Draft Technical Report
Hydrology and Water Quality

Volume 4

WyCoalGas Coal Gasification Project

Prepared for

U.S. Bureau of Land Management

August 1981

Woodward-Clyde Consultants
Three Embarcadero Center, Suite 700, San Francisco, CA 94111

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WATER SUPPLY SYSTEM

The proposed coal gasification plant would require 7,860 acre-feet of water per year; of this total, 6,020 acre-feet would be raw water from the water supply system, as shown in Table 2-1. All of the water diverted for the plant would be consumed, most by evaporation associated with plant operation. The proposed primary sources of water for the plant are LaPrele Reservoir and a flood appropriation from the North Platte River; ground water from two proposed well fields tapping the Madison and Lance-Fox Hills aquifers would function as a backup source to be used when the available surface water supply is not sufficient to meet plant demands. These proposed sources are described briefly below, and in detail in the following sections. Figure 2-1 shows their locations relative to the proposed plant site.

Water would be diverted from the North Platte River in T. 33 N., R. 71 W., sec. 7, and stored in Combs Reservoir, to be constructed in the Soldier Creek drainage near the mouth of the creek. The river diversion point has a direct flow right of 201.2 cfs, not to exceed 26,539 acre-feet in any one year for storage, and a 1974 priority date. Combs Reservoir has a 1974 storage right for 26,539 acre-feet. The potential yield of the North Platte diversion has been calculated using an operation model of the North Platte River developed by the Wyoming Water Resources Center (Wei 1977; Akerbergs 1981). The model shows that water would be available for diversion to WyCoalGas only in years of very high flow.

LaPrele Reservoir, located in T. 32 N., R. 73 W., operates under two permits with priority dates of 1905 and 1909. WyCoalGas's rights to water from LaPrele Reservoir result from an agreement

TABLE 2-1

WATER BALANCE: WYCOALGAS GASIFICATION PLANT AND WATER SUPPLY SYSTEM

Water	Gallons per Minute	Acre-Feet per Year
Inputs		
Coal Moisture	1,065	1,718
Water Supply System	5,100	8,020
Miscellaneous	76	123
	6,241	9,861
Outputs		
Process Consumption	1,297	2,092
Evaporation	3,417	5,306
In Ash and Sludge	287	463
Combs Reservoir Evaporation	1,240	2,000
	6,241	9,861

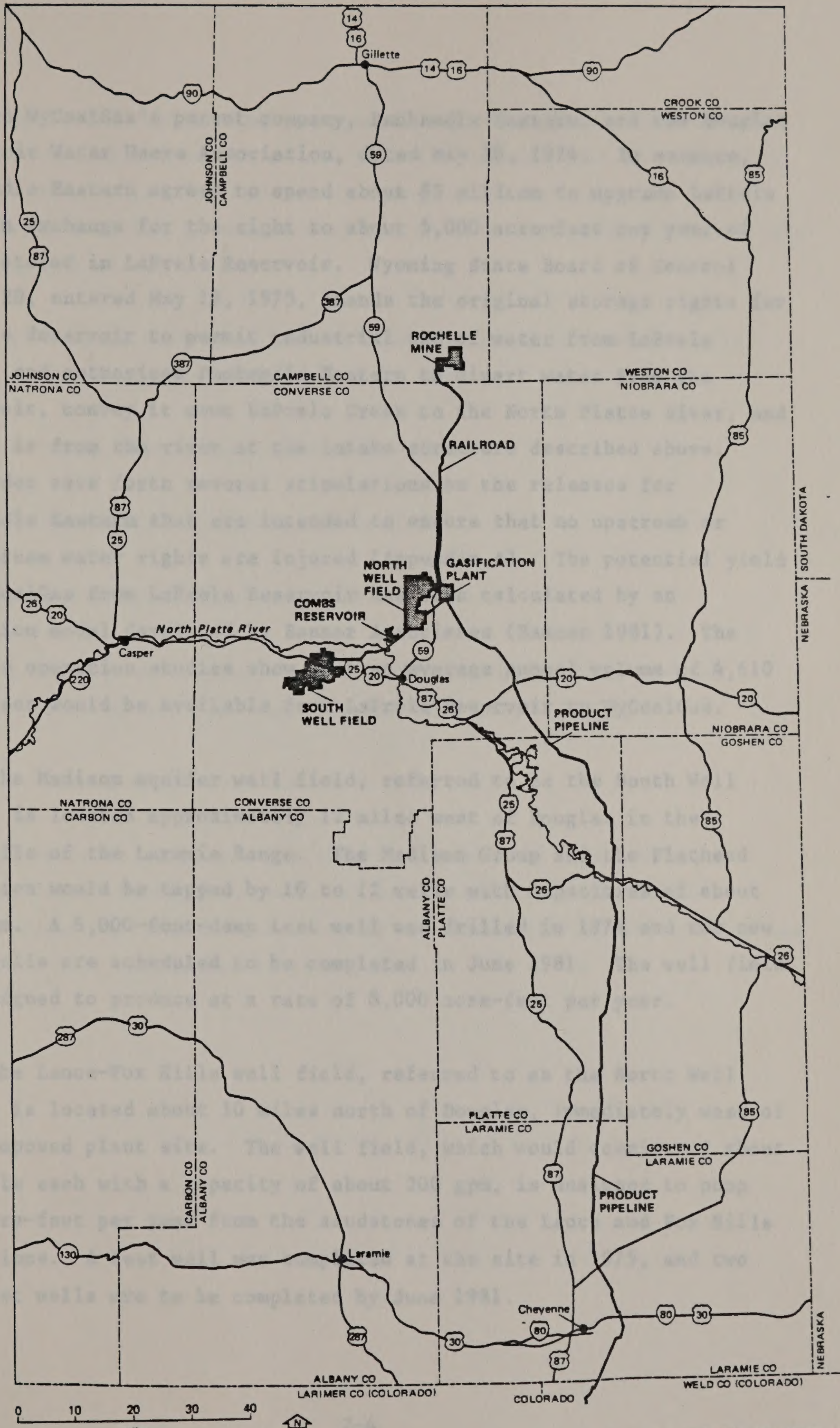

Figure 2-1. PROJECT LOCATION

between WyCoalGas's parent company, Panhandle Eastern, and the Douglas Reservoir Water Users Association, dated May 28, 1974. In essence, Panhandle Eastern agreed to spend about $5 million to upgrade LaPrele Dam, in exchange for the right to about 5,000 acre-feet per year of water stored in LaPrele Reservoir. Wyoming State Board of Control Order 20, entered May 19, 1975, amends the original storage rights for LaPrele Reservoir to permit industrial use of water from LaPrele Creek, and authorizes Panhandle Eastern to divert water from the reservoir, convey it down LaPrele Creek to the North Platte River, and divert it from the river at the intake structure described above. The order sets forth several stipulations on the releases for Panhandle Eastern that are intended to ensure that no upstream or downstream water rights are injured (Appendix A). The potential yield to WyCoalGas from LaPrele Reservoir has been calculated by an operation model developed by Banner Associates (Banner 1981). The LaPrele operation studies show that an average annual volume of 4,610 acre-feet would be available from LaPrele Reservoir to WyCoalGas.

The Madison aquifer well field, referred to as the South Well Field, is located approximately 12 miles west of Douglas in the foothills of the Laramie Range. The Madison Group and the Flathead Formation would be tapped by 10 to 12 wells with capacities of about 450 gpm. A 6,000-foot-deep test well was drilled in 1974 and two new test wells are scheduled to be completed in June 1981. The well field is designed to produce at a rate of 8,000 acre-feet per year.

The Lance-Fox Hills well field, referred to as the North Well Field, is located about 10 miles north of Douglas, immediately west of the proposed plant site. The well field, which would consist of about 20 wells each with a capacity of about 200 gpm, is designed to pump 650 acre-feet per year from the sandstones of the Lance and Fox Hills formations. A test well was completed at the site in 1975, and two new test wells are to be completed by June 1981.

WyCoalGas has proposed to operate its water supply system in a manner that maximizes the amount of surface water used and minimizes ground-water use. The sources are proposed to be used with the following priority to ensure that the plant's demand of 16.5 acre-feet per day are met:

1. Seepage from LaPrele Dam, which by Board of Control Order 20 is charged to WyCoalGas
2. North Platte direct diversion water
3. Releases from LaPrele Reservoir
4. Water from Combs Reservoir
5. Ground water from the South Well Field, up to a maximum rate of 5.5 acre-feet per day (2.8 cfs, 1,250 gpm)
6. Ground water from the North Well Field.

In addition, if surplus water should be available from the North Platte River beyond that needed to meet plant needs, it would be diverted to fill Combs Reservoir, if the reservoir is not full and has not been full during the current year.

Chapter 3
SOUTH WELL FIELD

3.A INTRODUCTION

The South Well Field is located at the northern end of the Laramie Mountains and at the southern end of the Powder River Basin. Near the site, elevations range from about 6,600 feet along a ridge south of the well field and near the heads of Box Elder Canyon and Little Box Elder Creek to about 5,000 feet in the Platte River floodplain. Several small creeks flow north out of the Laramie Mountains in the vicinity of the well field, toward the North Platte River. The main creeks are Box Elder Creek, Little Box Elder Creek, and LaPrele Creek. The only major surface-water body in the area is LaPrele Reservoir, a man-made lake formed by damming LaPrele Creek near the foothills of the uplands. Precipitation along the flanks of the Laramie Mountains averages 16 to 17 inches per year, but precipitation in the North Platte valley averages only 14 inches per year (Tay and Munson 1970).

The geology of the South Well Field area has been studied by Barnett (1914), Barlow (1950), and Rapp (1953). Banner Associates (1981) described the stratigraphy and mapped the geologic structure in the vicinity of the South Well Field. Hydrogeologic studies in the vicinity of the South Well Field have been conducted by Boner et al. (1974); Mancini (1976); Panhandle Eastern (1973, 1974, 1975); and Banner Associates (1980, 1981). Boner et al. (1976) gave a general geologic and hydrologic description of the Madison Formation along the northern and northeastern flanks of the Laramie Mountains.

In preparation of this Technical Report, existing geologic and hydrologic literature was reviewed, and state and federal agencies,

private consultants, and university faculty were contacted. A conceptual hydrogeologic model was developed, from which a numerical model was designed and used to simulate the hydrologic effects of pumping from the South Well Field. An assessment of hydrologic impacts was made, based upon the numerical simulations, and a monitoring system was designed. Where hydrologic impacts were predicted, measures were considered that would mitigate the impacts.

3.B THE PALEOZOIC AQUIFER SYSTEM

The Paleozoic aquifer system, defined for this study to include the Flathead, Madison, and Casper formations, is an important regional source of water. The major water-bearing units in the aquifer system are the Mississippian-age Madison Group and the adjacent hydraulically connected strata. The Madison Group is found in parts of Wyoming, Montana, North and South Dakota, and Canada, covering an area of more than 180,000 square miles. Composed largely of limestone and dolomite, the Madison Group is a source of water for domestic, stock, industrial, and agricultural users. In the Powder River Basin and the Black Hills region, about 30,000 acre-feet per year are produced from the Paleozoic aquifer (BLM 1980). The Paleozoic aquifer has not been fully developed, and is a potential source of water supply for large-scale energy development (USGS 1975).

The Paleozoic aquifer has been described in detail on a regional basis in several recent studies (Konikow 1976; Cooley, Naff, and Konikow 1980; WCC 1980). All of these studies have implied that the Paleozoic aquifer system on the flanks of the Laramie Mountains is poorly connected in a hydraulic sense to the Paleozoic aquifer system in the Powder River Basin. The Paleozoic aquifer system on the flanks of the Laramie Mountains was not discussed in detail in any of the previous studies. Therefore, the focus of this investigation was the

hydrogeology of the Paleozoic aquifer on the flanks of the Laramie Mountains in the vicinity of the South Well Field.

3.B.1 Hydrogeology

In the vicinity of the South Well Field, the major water-bearing units in the Paleozoic aquifer system are the sandstones and carbonates of the Flathead, Madison, and Casper formations. These units outcrop at the South Well Field in a narrow sinuous band, at most only a few miles wide, that trends approximately east-west along the flanks of the Laramie Mountains; see Figure 3-1.

The Madison Formation in the vicinity of the South Well Field is about 200 feet thick, as shown in the geologic column in Figure 3-2, and it thickens gradually toward the north. Here it is composed primarily of blue-gray, cherty, sandy, massive limestone and dolomite, with small interbeds of siltstone, chert, and sandstone (Figure 3-3). The carbonates are probably dense, with low primary porosity and permeability. Fracturing is common along interbeds and in the chert zones (Boner et al. 1976). The water yielding characteristics of the Madison Formation in the vicinity of the South Well Field probably result from well-developed zones of secondary porosity and permeability. Paleokarst features are present in the upper part of the formation in this area (Banner Associates 1981). The solution features are reported to be infilled, with well-cemented breccias in the subsurface (Huntoon 1981). Boner et al. (1976) described the secondary permeability characteristics of the Madison Formation in the outcrops exposed in the valleys of Cottonwood Creek, Little Box Elder Creek, and Box Elder Creek. Along Cottonwood Creek and Little Box Elder Creek, they reported, the limestones in the middle and upper units of the Madison Formation have extensive secondary permeability in the form of fist-sized and smaller solution openings, and sinkholes are indicated along Cottonwood Creek by small depressions in the alluvium.

3-4

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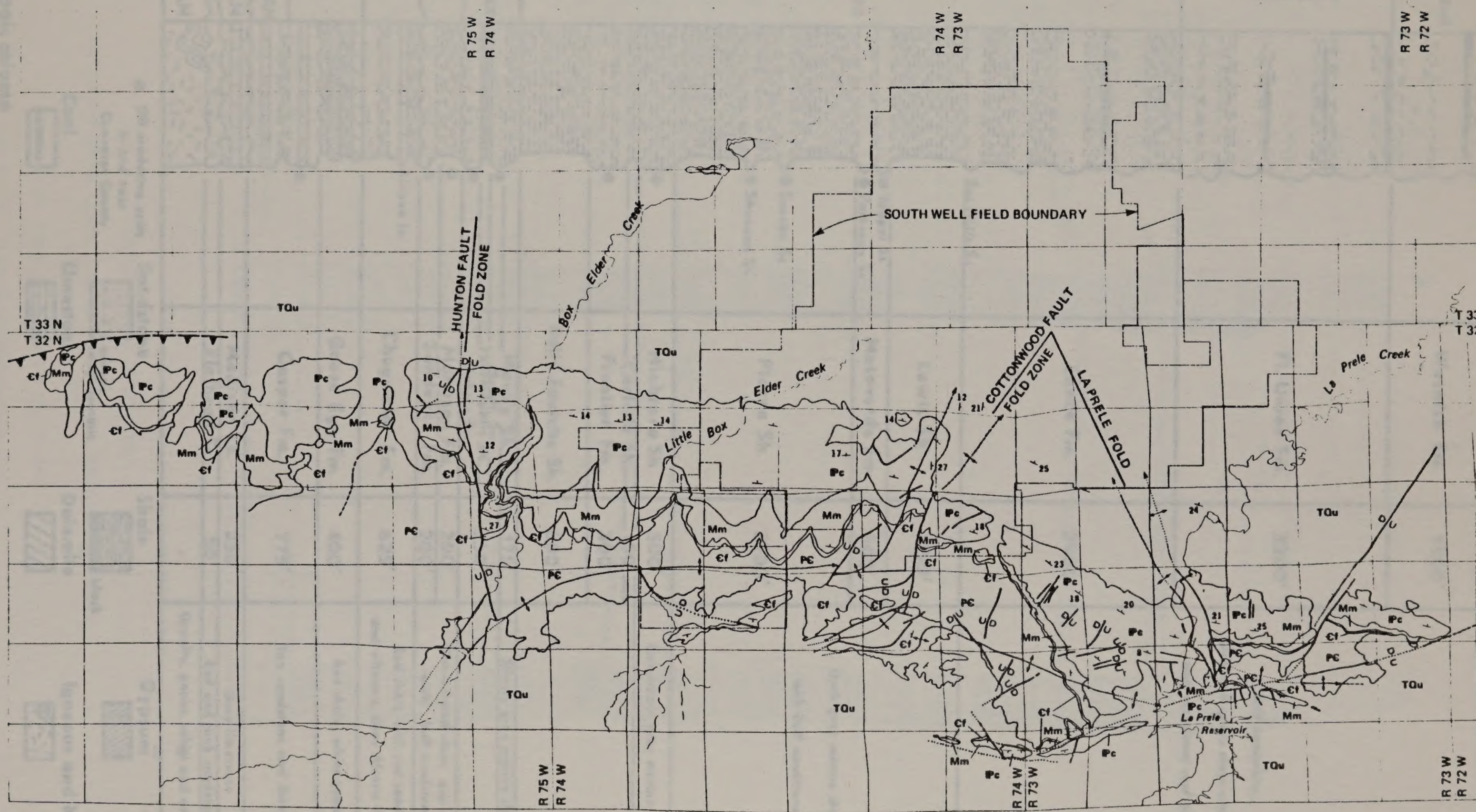


SOURCE:
Blackstone et al, 1976
Huntoon and Richter, 1981.

EXPLANATION

FAULT: Dashed where fault dies out, dotted where concealed

U Upthrown side

D Downthrown side

40 Estimated displacement in feet

Thrust fault, teeth in upper plate

ANTICLINE: Trace of axis and direction of plunge dotted where fold is concealed

SYNCLINE: Trace of axis and direction of plunge dotted where fold is concealed

21 STRIKE AND DIP OF BEDS

LITHOLOGIC CONTACT

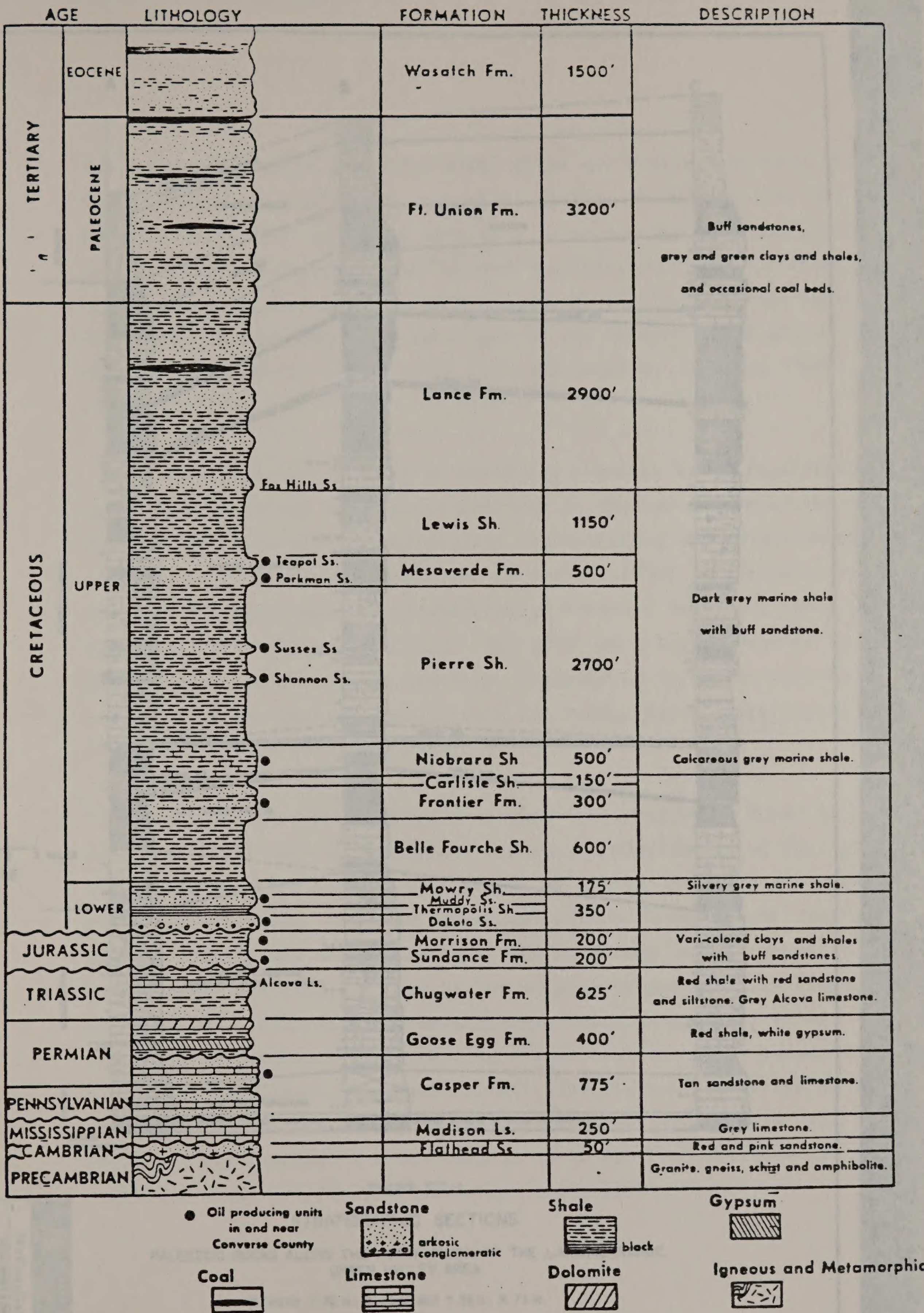
ROCK UNITS

TQu	Tertiary and Quaternary rocks, undivided, (includes Alluvium)
Pc	Casper Formation
Mm	Madison Formation
Cf	Flathead (?) sandstone
PC	Precambrian crystalline and metamorphic rocks, (undivided)

Fig 3-1

SURFICIAL GEOLOGY IN THE VICINITY OF THE GREEN VALLEY WELL FIELD

GRAPHICS gechprint 7/29/81



Geologic column

Fig. 3-2 (Lane, Root, Glass, 1972)

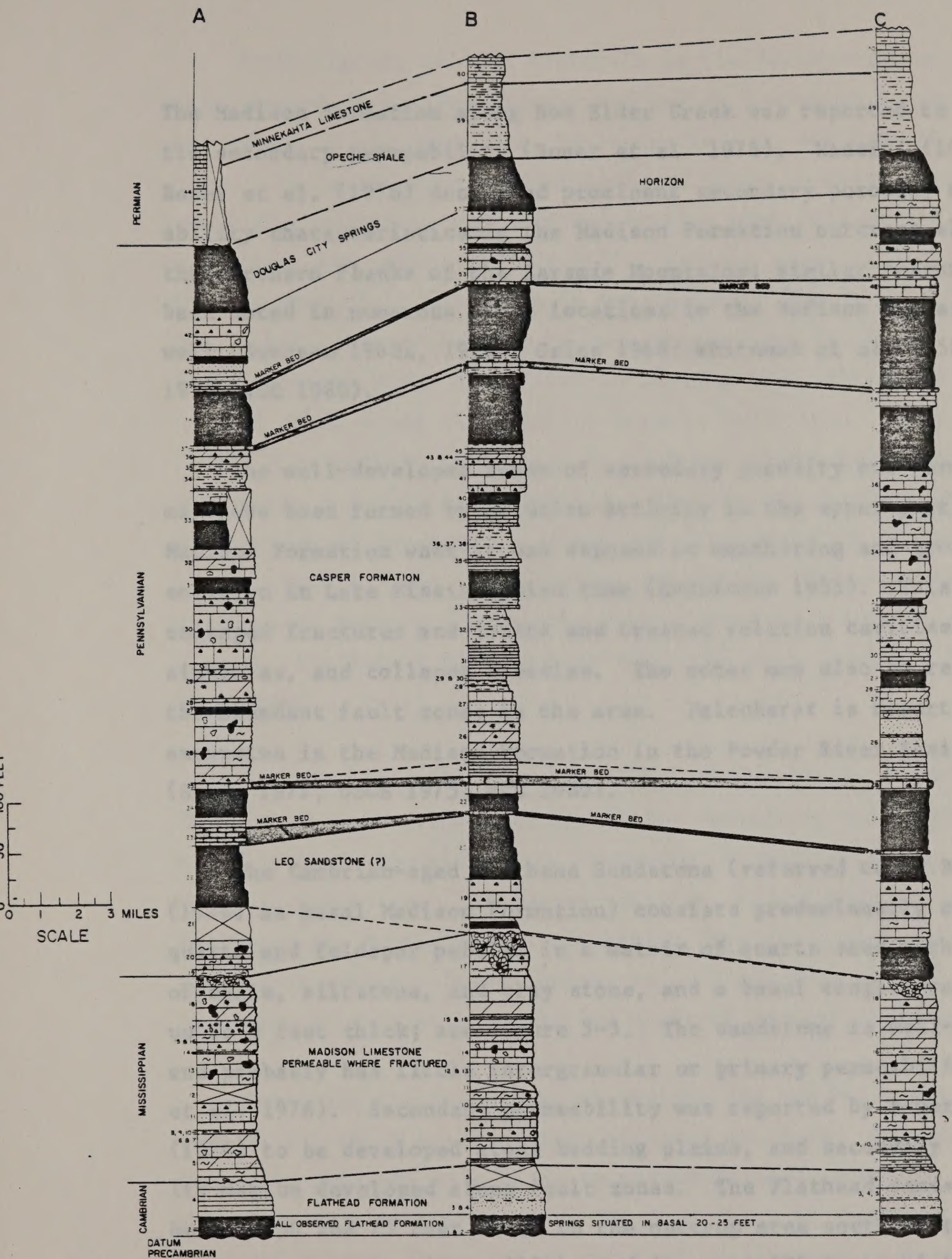


FIGURE III-1

STRATIGRAPHIC SECTIONS

PALEOZOIC ROCKS ALONG THE NORTH FLANK OF THE LARAMIE RANGE
GREEN VALLEY AREA

BETWEEN T. 32 N., R. 75 W. AND T. 32 N., R. 73 W.

NUMBERS CORRESPOND TO NUMBERED LITHOLOGIC DESCRIPTIONS FOR THE RESPECTIVE COLUMN IN APPENDIX A.

BANNER ASSOCIATES INC.
CONSULTING ENGINEERS & ARCHITECTS
620 PLAZA CT LARAMIE, WYOMING

WyCoalGas Projects
SURFACE GEOLOGY & GROUNDWATER INVESTIGATIONS OF MORTONS & GREEN VALLEY WELL FIELDS

STRATIGRAPHIC SECTIONS
VALLEY AREA

DAMC	PWH	3-81	SHOWN	1803-1	FIGURE III-1

Figure 3-3 Stratigraphic Sections of Paleozoic Rocks on the North Flank of the Laramie Range, Green Valley Well field Area

The Madison Formation along Box Elder Creek was reported to have little secondary permeability (Boner et al. 1976). Mancini (1976) and Boner et al. (1976) described prominent secondary porosity and permeability characteristics in the Madison Formation outcrops all along the northern flanks of the Laramie Mountains; similar features have been noted in numerous other locations in the Madison Formation as well (Swenson 1968a, 1968b; Gries 1968; Whitcomb et al. 1958; USGS 1975; WCC 1980).

The well-developed zones of secondary porosity and permeability may have been formed by solution activity in the upper part of the Madison Formation when it was exposed to weathering and ground-water solution in Late Mississippian time (Andrichuk 1953). This weathering enlarged fractures and joints and created solution cavities, caves, sinkholes, and collapse breccias. The zones may also be related to the abundant fault zones in the area. Paleokarst is reported to be extensive in the Madison Formation in the Powder River Basin region (Sando 1977; USGS 1975; WCC 1980).

The Cambrian-aged Flathead Sandstone (referred to by Boner et al. (1976) as basal Madison Formation) consists predominantly of rounded quartz and feldspar pebbles in a matrix of quartz sand with interbeds of shale, siltstone, and clay stone, and a basal conglomerate ranging up to 5 feet thick; see Figure 3-3. The sandstone is well-cemented and probably has little intergranular or primary permeability (Boner et al. 1976). Secondary permeability was reported by Boner et al. (1976) to be developed along bedding plains, and secondary permeability may be developed along fault zones. The Flathead sandstone is between 50 and 75 feet thick in the outcrop area south of the well field (Banner Associates 1981), and is up to 400 feet thick to the northwest in Natrona County (Crist and Lowry 1972).

Overlying the Madison Formation is the Pennsylvanian- and Permian-aged Casper Formation. The Casper Formation is geologically equivalent to the Minnelusa, Tensleep, Amsden, and Hartville formations. It is composed predominantly of fine- to medium-grained sandstone that is weakly cemented and friable with interbedded limestones, dolomites, and shales (Figure 3-3). Primary porosity and permeability are probably fairly high in the sandstone beds in the Casper Formation. Hydraulic connection between the Madison and Casper formations is reported by Boner et al. (1976) to be in all likelihood very good in most areas along the northern Laramie Mountains. Loury and Ranld (1981) also suggest that there is good hydrologic connection between the Casper and Madison formations. Huntoon and Richter (1981) mapped the geology of the area in detail and concluded that vertical hydraulic connection between the Madison and Casper formations is virtually nonexistent because of the existence of areally extensive confining layers. The Casper Formation is about 800 feet thick at the South Well Field.

Stratigraphically above the Casper Formation is a 1000- to 1500-foot sequence of predominantly clastic sediments, mainly siltstones and claystones comprising the Goose-Egg, Spearfish, Sundance, and Morrison formations. The water-yielding characteristics of these sediments are poorly known. Overlying them is a thick sequence of Cretaceous shales. These shales, up to 5,000 feet thick, are generally massive with a very low vertical permeability, (WCC 1981).

Overlying the Cretaceous shales are the Fox Hills and Lance formations, which are important regional aquifers. The Fox-Hills Formation consists of a fine- to medium-grained, slightly calcareous sandstone that is about 350 to 400 feet thick at the North Well Field site. The Lance Formation is composed of alternating beds of very fine- to fine-grained sandstones and carbonaceous shales, and varies

in thickness from 3,000 feet in Natrona County (Crist and Lowry 1973) to between 1,600 and 2,500 feet in Niobrara County (Whitcomb 1965).

The Tertiary-aged Fort Union and Wasatch formations mantle all older rocks in the Powder River Basin except in the surrounding mountain ranges and uplands. These sediments are composed of sandstone, siltstone, shale, and coals. Small quantities of water are supplied to stock and domestic wells by these sediments.

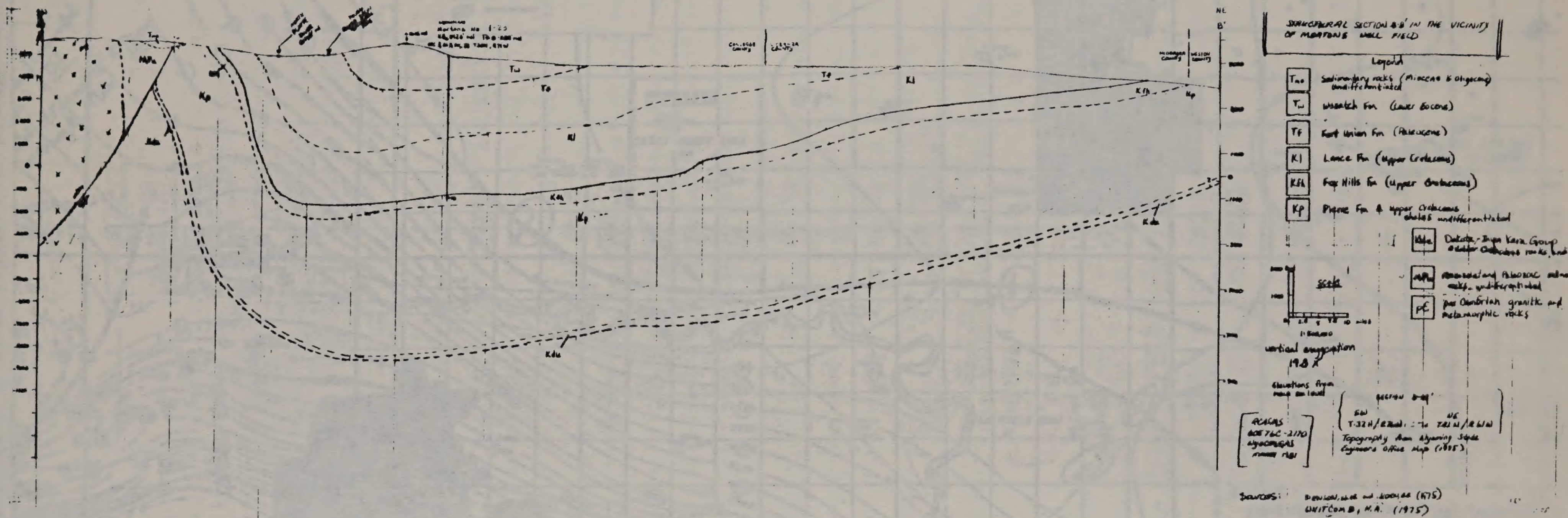
In the vicinity of the South Well Field, the White River Formation is exposed at the surface. The White River Formation consists of light-gray, soft sandstone, white tuffaceous clay, siltstone, and arkosic sandstone. These deposits yield sufficient quantities of water for stock and domestic uses.

3.B.2 Structural Geology

The South Well Field is in a structurally complex area on the flanks of an asymmetrical incline at the southern end of the Powder River Basin, and on the northern flanks of the Laramie Mountains. Many faults and folds that trend across the axis of the anticline have been mapped in the area. A large thrust fault may lie to the north of the well field, and the pre-Tertiary strata in the area dip steeply to the north; see Figures 3-1 and 3-4. The structural geology of the well-field area has been mapped by Banner Associates (1981), and the regional structural geology has been mapped by Zapp (1951) and Petroleum Information Company (1980) (Figure 3-5).

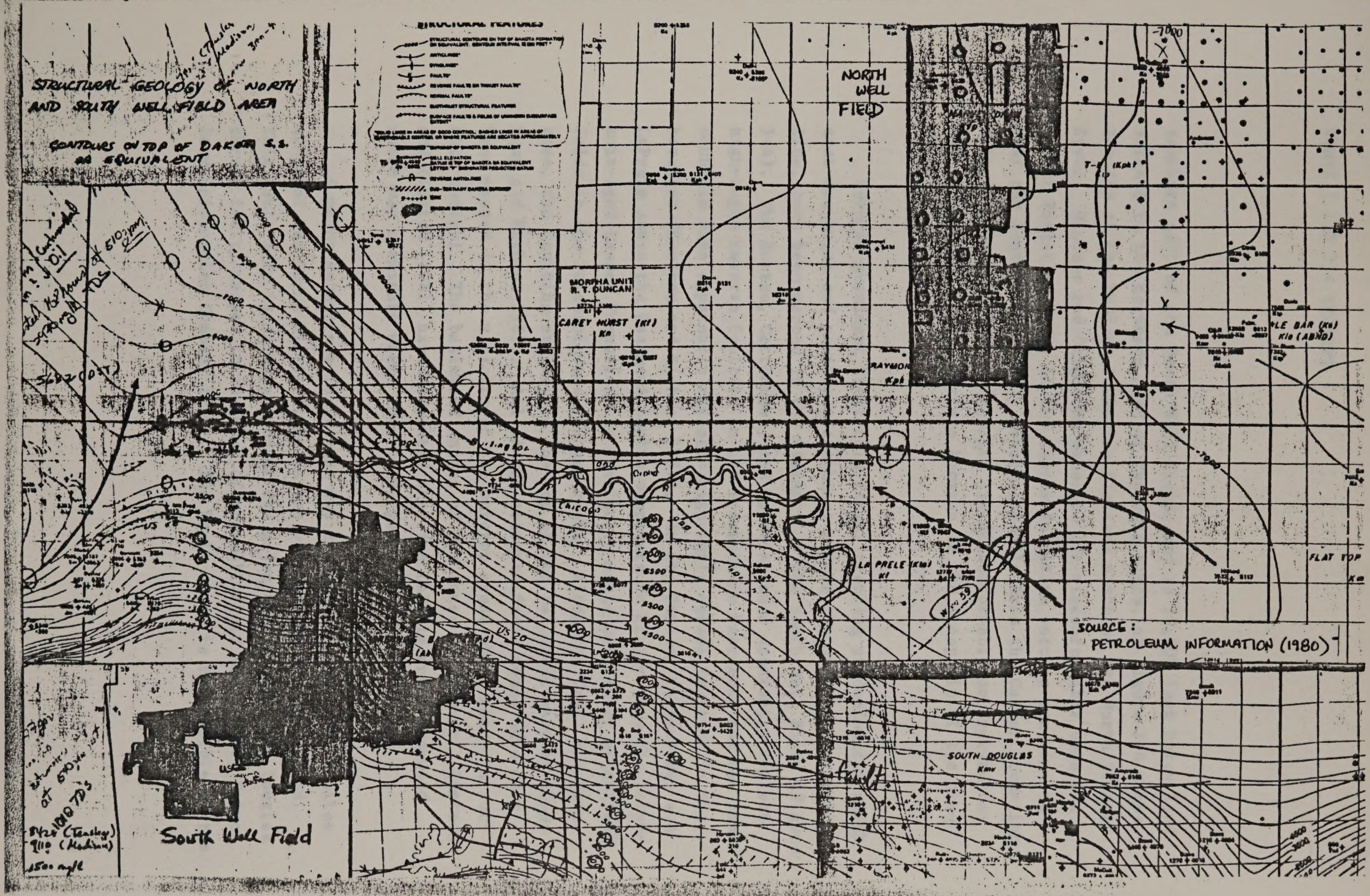
The pre-Tertiary strata in the vicinity of the South Well Field dip steeply to the north off the flanks of the asymmetrical anticline that comprises the northern edge of the Laramie Mountains. Dips along the outcrop areas are generally 25 to 30 degrees (Wester 1981). As a result of these steep dips, the Madison Formation outcrops in the

Fig. 3-4



STRUCTURAL SECTION B-B' IN THE VICINITY OF MORTONS WELL FIELD
Legend
Tw
Wasatch Fm (Lower Eocene)
Tf
Fort Union Fm (Paleocene)
Kl
Lance Fm (Upper Cretaceous)
Kfh
Fox Hills Fm (Upper Cretaceous)
Kp
Pierre Fm & upper Cretaceous shales undifferentiated
pC
pre Cambrian granitic and metamorphic rocks
scale
vertical exaggeration
Elevations from mean sea level
Topography from Wyoming State Engineers Office Map
Sources:
Kl
Kp
Kdu
Tw

Fig. 3-5


STRUCTURAL GEOLOGY OF NORTH AND SOUTH WELL FIELD AREA
CONTOURS ON TOP OF DAKOTA S.S. OR EQUIVALENT
STRUCTURAL FEATURES
NORTH WELL FIELD
MORPHA UNIT
R. T. DUNCAN
CAREY HURST (Kf)
LA PRELE (Km)
FLAT TOP
SOUTH DOUGLAS
South Well Field
SOURCE: PETROLEUM INFORMATION (1980)

southern part of the South Well Field, and is 10,000 feet below land surface in the northern part of the well field, as Figure 3-4 shows. The dip of the Madison Formation flattens north of the North Platte River. Miocene and Oligocene deposits lie disconformably upon the Casper Formation north of the Casper Formation outcrop zone in and near the South Well Field. Beyond one mile from the Casper Formation outcrop zone the Miocene deposits lie disconformably on Cretaceous-aged shales and younger strata because of the steep dip of the pre-Tertiary strata.

Several prominent fault-fold zones, trending predominantly northeast-southwest and northwest-southeast across the axis of the anticline, have been mapped in the vicinity of the South Well Field (Figure 3-4). The Hunton, Cottonwood, and LaPrele zones apparently reflect high-angle reverse faulting in the Precambrian basement, and the Table Mountain zone apparently reflects high-angle normal faulting in the basement (Huntoon and Richter 1981). In the Hunton, Cottonwood, and LaPrele zones the basement faults propogate no higher than the Paleozoic-aged Casper Formation, as the faults merge into sharp monoclinal folds in the Paleozoic and younger rocks. Along the Table Mountain zone, the faulting extends to the top of the Paleozoic section (Huntoon and Richter 1981). All of the traverse fault zones have only been mapped in the vicinity of the outcrop areas where there is surface control. The basinward extent of the zones is unknown. Huntoon and Richter (1981) have suggested that the LaPrele and Cottonwood zones may terminate where they converge.

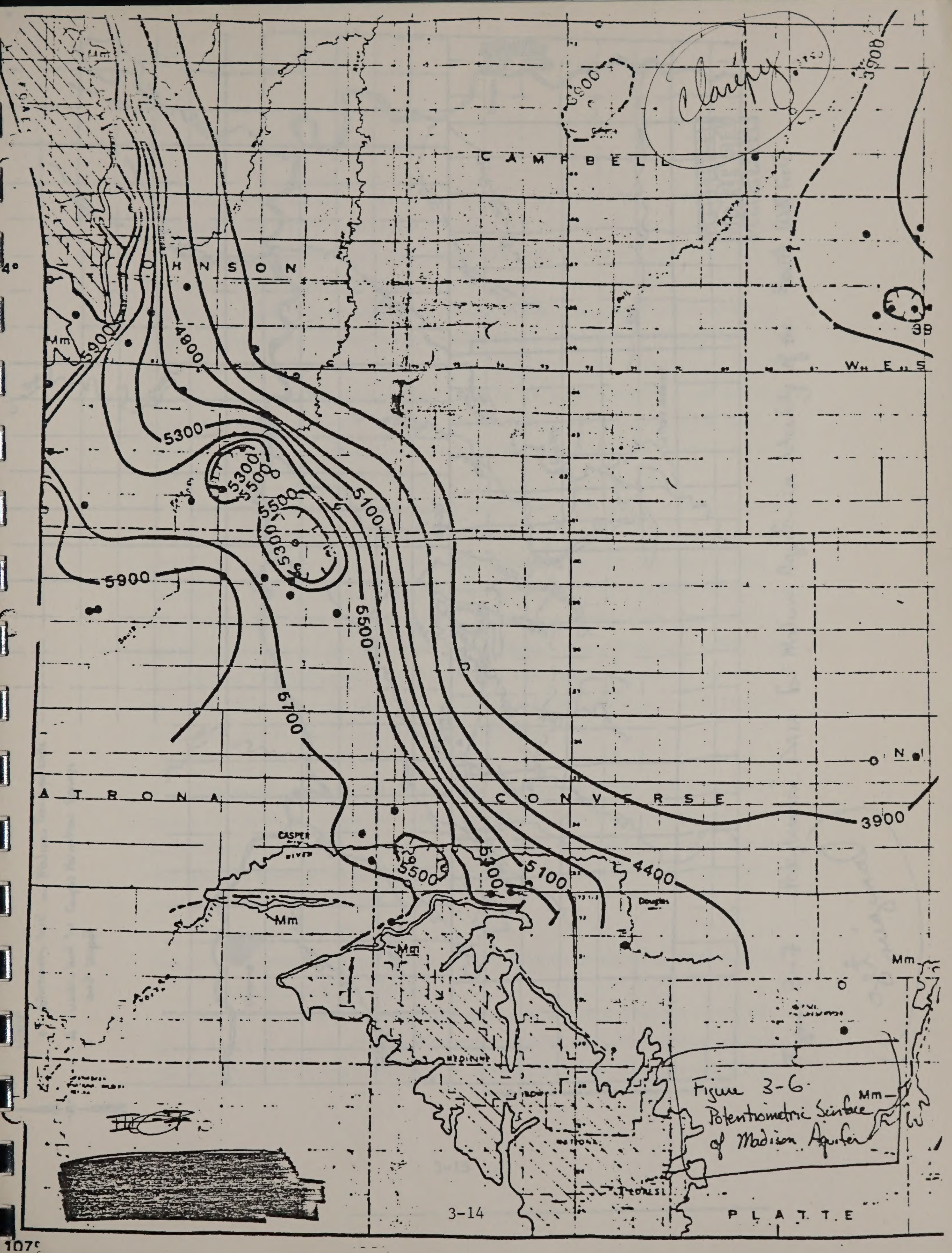
A major subsurface fault zone may trend east-west about 3 miles south of the North Platte River in the vicinity of the well field. This fault zone is an extension of the major thrust zone, the Douglas thrust fault, mapped to the west of the well field (Zapp 1951; Petroleum Information Company 1980). The fault trace is not visible at the

surface east of the Hunton fault-fold zone, and insufficient holes have been drilled to delineate it in the subsurface, but the existence of a fault zone is consistent with the thrust fault uplift hypothesis for the origin of the Laramie Mountains (Figure 3-4). Displacement of the Madison Formation may well occur along this thrust zone north of the well field. West of the well field, in a petroleum test well in T. 32 N., R. 75 W., sec. 6, Mesozoic rocks were penetrated at 3,500 feet after a full section of Paleozoic rock and 1,100 feet of Precambrian rock had been penetrated. The thrust fault, and the other fault zones along the northern part of the Laramie Mountains in the vicinity of the well field, may well divide the Madison and Casper formations into a group of discontinuous blocks that are poorly connected hydrologically.

3.B.3 Hydrologic Setting

The potentiometric surface of the Paleozoic aquifer in the Powder River Basin has recently been mapped by Miller and Strausz (1980) and by Swenson et al. (1976), and is shown in Figure 3-6. Pontentiometric data are abundant near the Black Hills, where there are many wells and springs, but data points are few outside of the Black Hills Uplift. All potentiometric data points for the Madison aquifer system in the vicinity of the South Well Field are shown in Figure 3-7.

The potentiometric surface of the Paleozoic aquifer system in the vicinity of the South Well Field ranges from about 5,600 feet in outcrop areas; to less than 5,440 feet in outcrops along LaPrele Reservoir; to about 5,300 feet at the Douglas City Springs, at South Well Field #1, and in the LaPrele Creek valley; to about 5,200 feet in the Box Elder Creek valley. The potentiometric surface apparently dips steeply into the Powder River Basin just north of the well field. Very steep dips in the potentiometric surface are known to occur to the northwest in the vicinity of the Salt Creek Oil Fields.


CAMPBELL
JOHNSON
WHEES
ATRONA
CONVERSE
PLATTE
CASPER
Douglas
Mm
5900
4800
5300
5300
5500
5500
5300
5100
5900
6500
6700
5500
5700
5100
4400
3900
3900
5900
Figure 3-6
Potentiometric Surface of Madison Aquifer
clarify

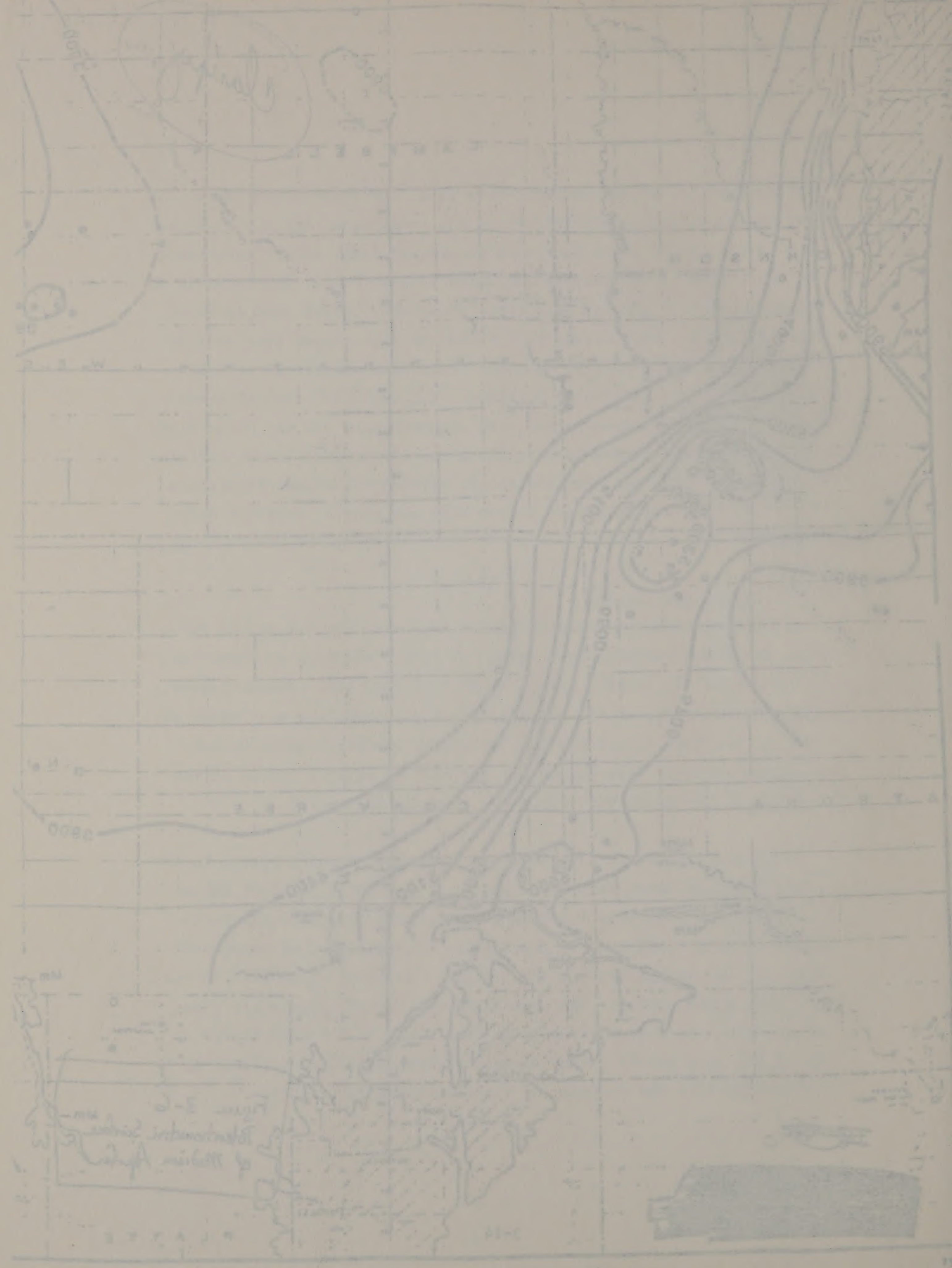


Figure 3-6
Potentiometric Surface of Madison Aquifer

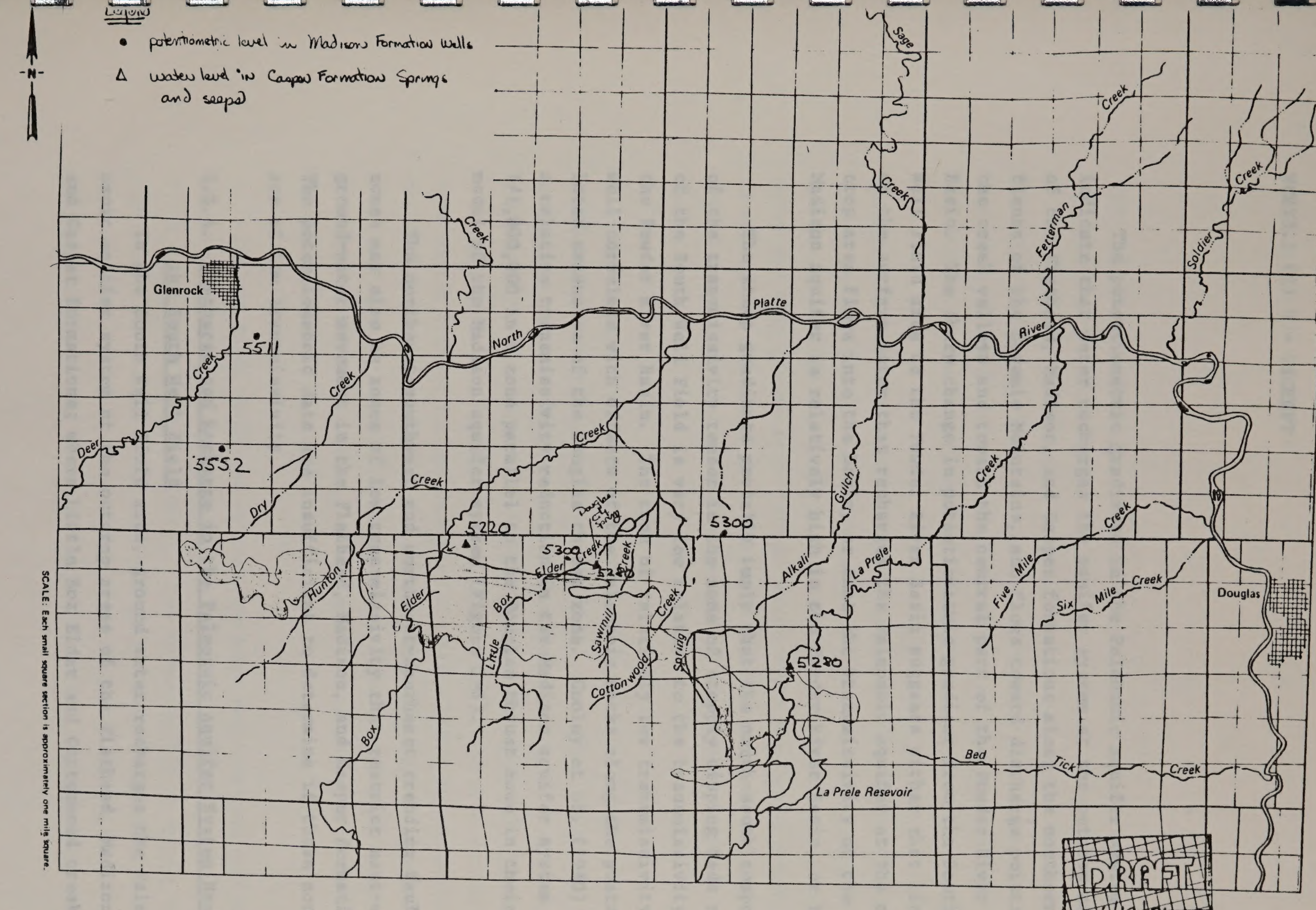


Figure 3-7 Potentiometric DATA for Madison Aquifer in Vicinity of the South Well Field

get original

The potentiometric gradients in the Paleozoic aquifer system indicate that water recharges the aquifer system at the outcrop areas of the Flathead, Madison, and Casper formations along the northern flanks of the Laramie Mountains, and flows toward discharge points in the creek valleys and toward the central part of the Powder River Basin. The sharp change in potentiometric gradient from the South Well Field area to the Powder River Basin suggests either that little of the surface water that recharges the Paleozoic aquifer at the outcrop area flows into the basin, or that the transmissivity of the Madison aquifer is relatively high in the Powder River Basin, or both.

The steep gradients probably imply that the north-south component of the transmissivity tensor in the zone of steeply dipping beds north of the South Well Field is very low relative to the transmissivity in the Powder River Basin. The zone of relatively low transmissivity may well correlate with offsets of the Paleozoic rocks along the postulated extension of the Douglas thrust zone. Cooley et al. (1980) used a relative transmissivity reduction in the Madison aquifer system of 1/1,000,000 in a zone parallel to the Douglas thrust zone in their model of the Madison aquifer system (Figure 3-6).

The northeast-southwest and northwest-southeast trending fault zones may also be zones of low transmissivity that restrict east-west ground-water movement in the Flathead, Madison, and Casper formations. The potentiometric data are insufficient to determine if these zones are of low transmissivity.

3.B.4. <u>Discharge and Recharge in the Paleozoic Aquifer System Near the South Well Field</u>

In the South Well Field area, ground water recharges the Paleozoic aquifer system at the outcrop areas of the Flathead, Madison, and Casper formations; where Little Box Elder and Cottonwood creeks

cross the Madison Formation outcrops; and possibly at the northern end of LaPrele Reservoir; see Figure 3-8. Most of this water discharges at the Douglas City Springs, in LaPrele Creek below the reservoir, and the rest discharges either as seeps or flows into the central part of the Powder River Basin. The dominant direction of ground-water flow is parallel to the narrow band of Paleozoic outcrops.

Discharge. The major known discharge points for the Madison aquifer system in the vicinity of the South Well Field are the Douglas City Spring and springs and seeps in the Box Elder Creek valley. Ground water may also discharge to LaPrele Creek where the Casper Formation is exposed in the valley in T. 32 N., R. 73 W., secs. 21 and 22. Ground water flows out of the region toward the Powder River Basin.

The largest ground-water discharge point in the area is at the Douglas City Spring, in T. 32 N., R. 73 W., sec. 3dba. Although the spring was the only water supply source for the city of Douglas from 1923 to 1979, flow records from the spring are sparse. The average discharge from this spring is about 2 cfs, and measured discharges have varied between 1.4 and 3.8 cfs; see Table 3-1. Discharge from the spring varies seasonally and is greatest when flow is recorded at the lower gage on Little Box Elder Creek. The spring issues from the alluvium of Little Box Elder Creek, where the alluvium is underlain by the Casper Formation.

The Box Elder Creek valley contains many small springs and seeps issuing from the Madison Formation in T. 32 N., R. 75 W., sec. 12 and T. 32 N., R. 74 W., secs. 6 and 7. The stream valley is deeply incised, and the elevations of the Madison and Casper formation outcrops in the stream valley are lower here than elsewhere in the area. The valley probably serves as a discharge point for local flow systems in

fig. 3-8

fig 3-8

SCHEMATIC OF DISCHARGE IN THE MADISON AQUIFER SYSTEM

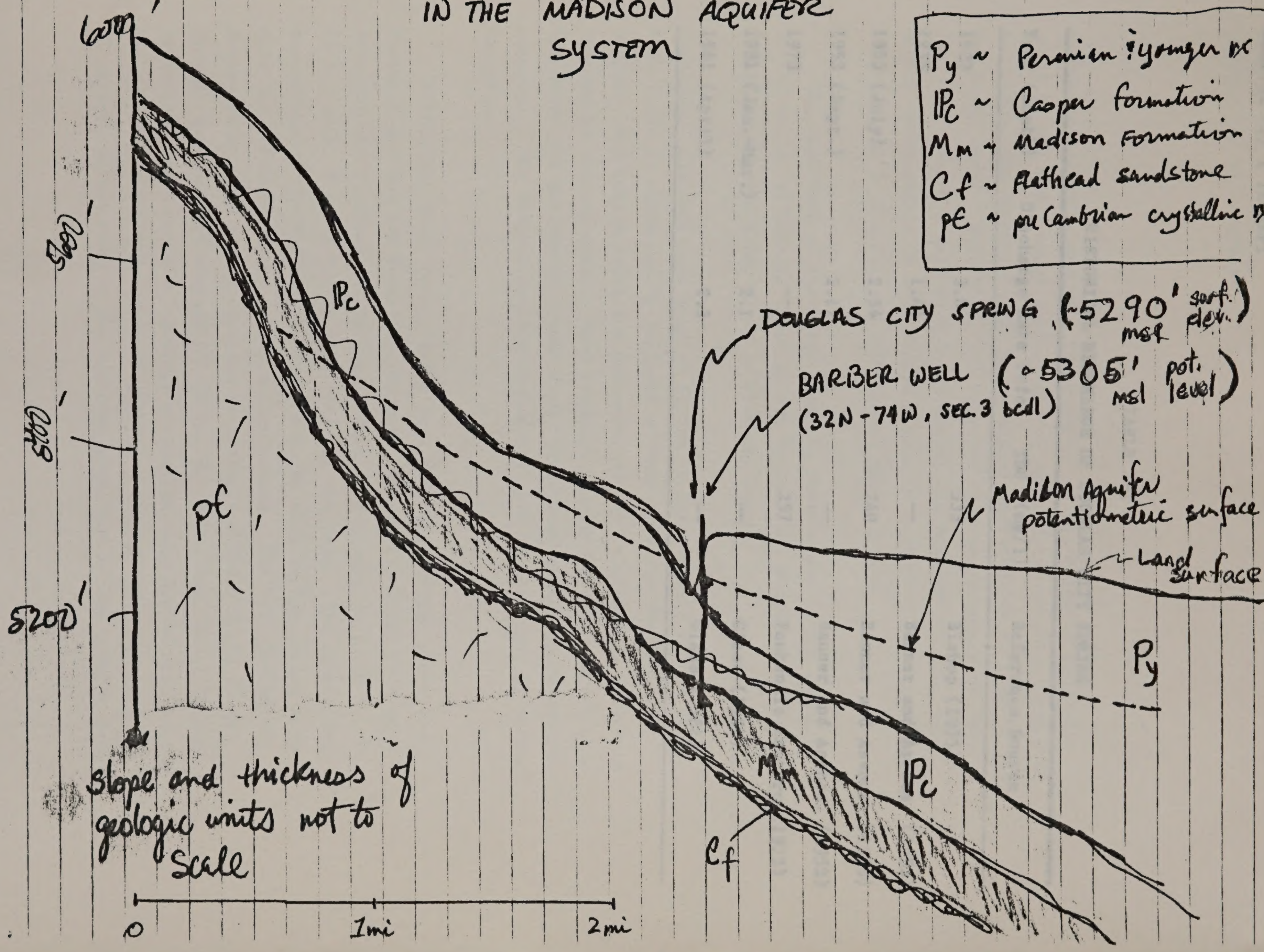


TABLE 3-1

HISTORICAL DISCHARGE OF DOUGLAS CITY SPRING

Year (month)	Discharge Rate (cfs)	TDS (mg/l)	Reference Source
1923	3.8	335	Bishop (1935)
1935	1.44	--	Banner and Assocs. (1953)
1953 (July)	2.54	240	Banner and Assocs. (1953)
1953 (Sept.)	2.17	--	Banner and Assocs. (1953)
1973	--	257	Panhandle Eastern (1973)
1981 (Jan.-Mar.)	2.1	--	Glass (1981)
1981 (April)	2.3	--	Glass (1981)

the Madison aquifer system. The quantity of discharge is generally small in Box Elder Creek valley, and is seasonally variable. Boner et al. (1976) and Mancini (1976) made several measurements of flow in the Box Elder Creek. Mancini (1976) reported that measurements on June 26, 1974, showed a gain of 6.5 cfs across the Madison outcrop, additional measurements in 1974 showed a gain of 0.50 to 0.83 cfs, and measurements in the fall of 1975 showed small losses.

The magnitude of discharge from the Madison and Casper formations in the valley of LaPrele Creek is not known. The magnitude of flow toward the Powder River Basin is also not known.

Recharge. The Paleozoic aquifer system in the vicinity of the South Well Field is recharged by influent streams crossing the Flathead, Madison, and Casper formation outcrops, and by infiltration of precipitation in outcrop areas. Most recharge probably occurs where Little Box Elder and Cottonwood creeks lose flow crossing Madison Formation outcrops. The Madison aquifer system may also be recharged by LaPrele Reservoir.

Little Box Elder Creek, which is a perennial stream above the Flathead and Madison formation outcrops, loses all of its flow when crossing the Flathead and Madison formation outcrops in T. 32 N., R. 74 W., secs. 8 and 9 during most times of the year. The creek flows downstream of the Madison Formation outcrop only during spring snowmelt and following large precipitation events. The U.S. Geological Survey maintained gaging stations on Little Box Elder Creek at the Precambrian-Flathead contact (T. 32 N., R. 74 W., sec. 9bda) during water-years 1975 to 1979. Average streamflow loss during this period was 1.1 cfs. Little Box Elder Creek has a flow greater than 0.5 cfs 95 percent of the time at the upstream gage, and a flow greater than

0.1 cfs only 15 percent of the time at the downstream gage (Figure 3-9).

Cottonwood Creek has been reported by Wester (1981) and by Boner et al. (1976) to gradually lose all of its flow when crossing the Flathead and Madison formation outcrops in T. 32 N., R. 74 W., secs. 13 and 14. On the basis of sporadic flow measurements, Wester (1981) estimated an average flow loss of about 0.75 cfs. Boner et al. (1976) measured a flow loss of 0.64 cfs on July 30, 1974. The annual average flow of Cottonwood Creek above the Madison Formation outcrop during the period 1974 to 1979 was estimated to be about 0.5 cfs, based on the ratio of drainage basin areas in the Cottonwood Creek and Little Box Elder Creek basins. Therefore, average annual flow losses at the Flathead and Madison formation outcrops are probably less than 0.5 cfs.

The lower end of LaPrele Reservoir and LaPrele Dam rest on outcrops of the Casper Formation. Seepage probably occurs from the reservoir but quantities are unknown. Seepage from the reservoir likely varies seasonally, as water levels in the reservoir are drawn down by the end of the irrigation season (see the section on LaPrele Reservoir). Water levels in the reservoir presently fluctuate between about 5,380 and 5,440 feet above mean sea level during normal operations, but because of restrictions placed on storage in 1971, reservoir levels between 1971 and 1979 did not exceed 5,426 feet. Water levels in the reservoir are greater than potentiometric level in the adjacent Casper Formation, and therefore, recharge would occur. This recharge probably discharges below the dam, where the Casper Formation is exposed along the creek for more than a mile.

The recharge that occurs to the Flathead, Madison, and Casper formation outcrops in the area by direct infiltration of precipitation

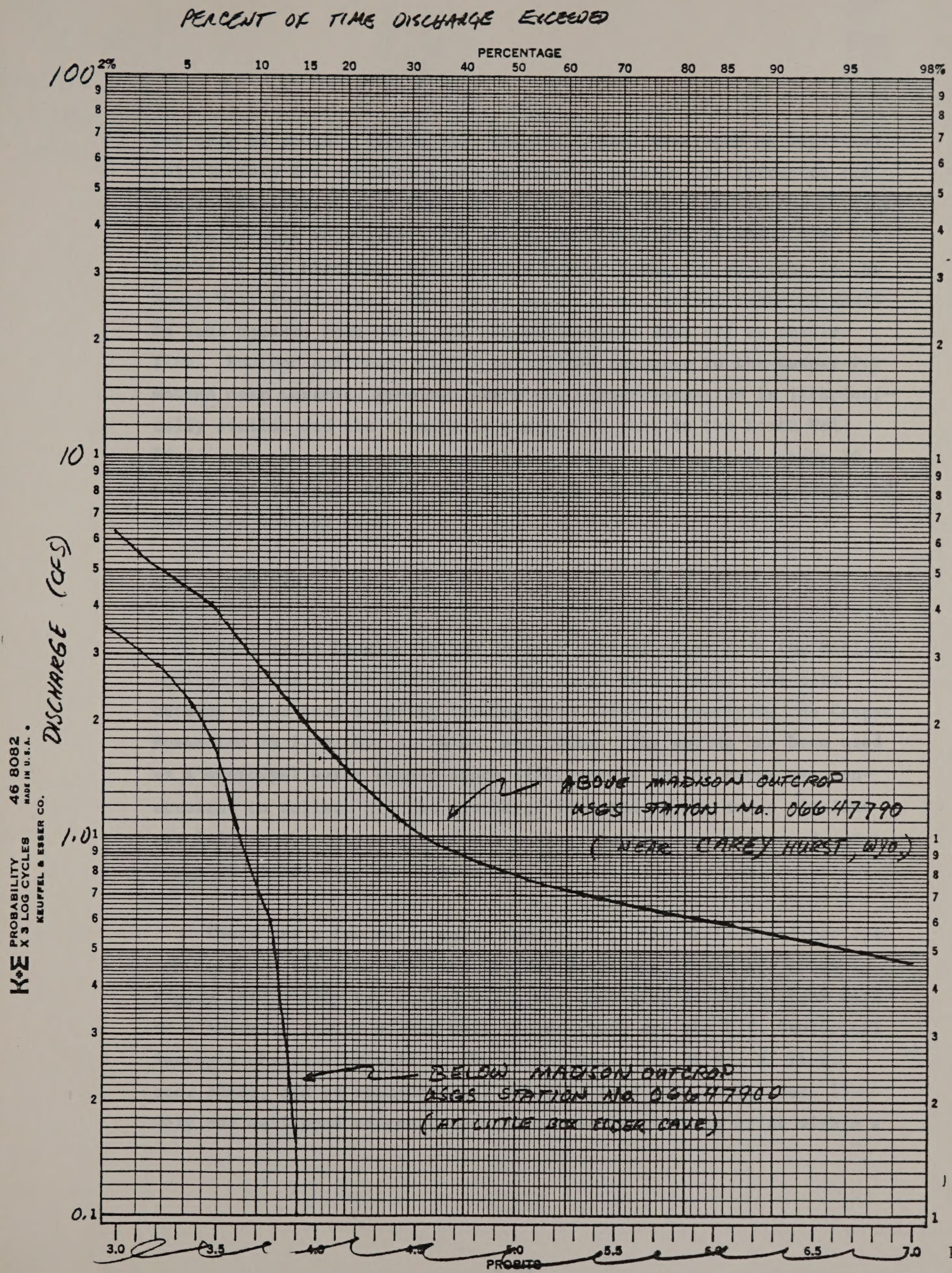


FIGURE 3-9. FLOW-DURATION CURVE FOR LITTLE BOX ELDER CREEK NEAR CAREY HURST, ... AND AT LITTLE BOX ELDER CAVE, NEAR CAREYHURST, WYOMING

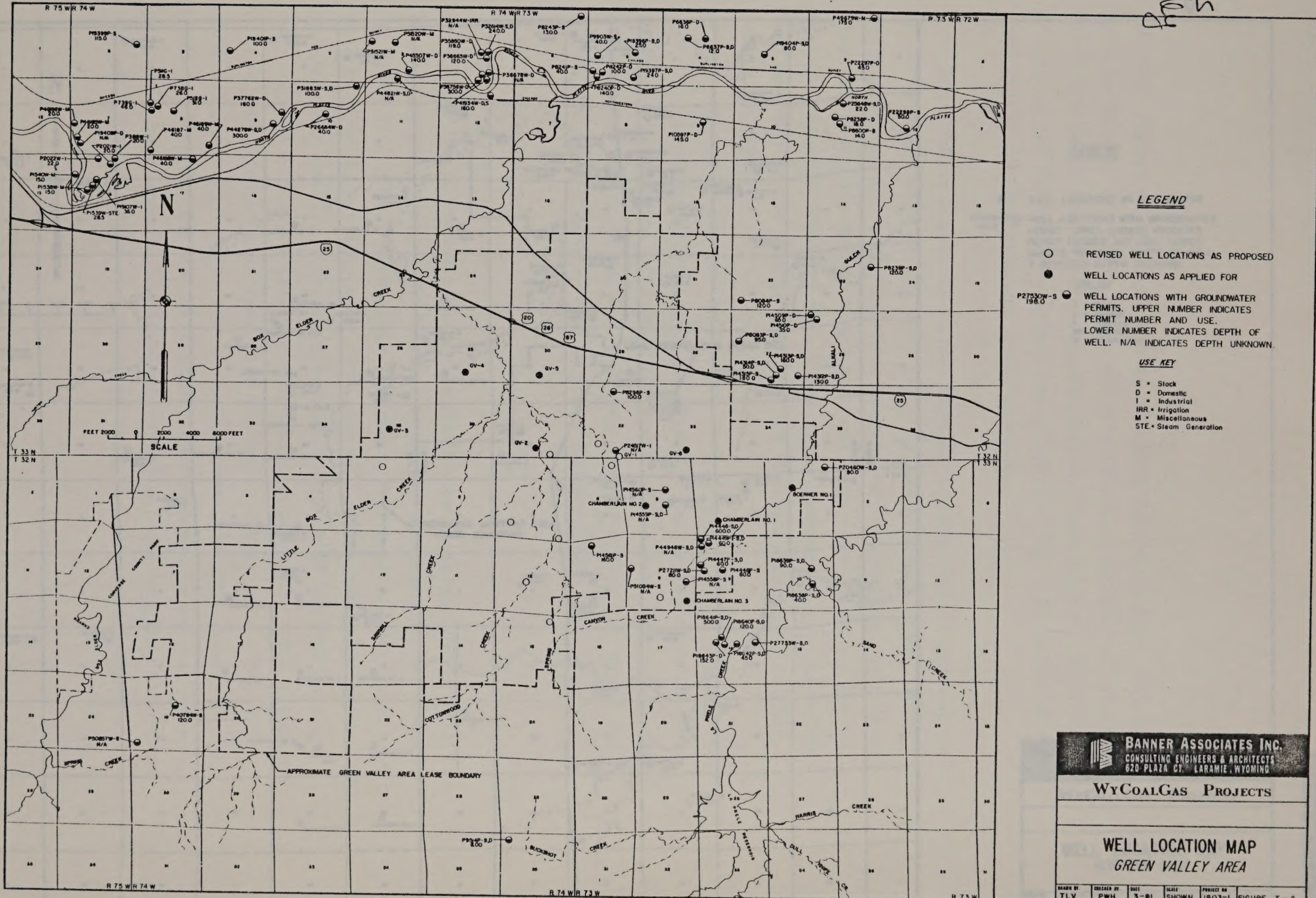
can only be roughly estimated. Mancini (1976) developed an empirical relationship for estimating the difference between precipitation and evapotranspiration as a function of elevation along the northern flank of the Laramie Mountains. The estimated difference is about 2.8 inches at the Flathead, Madison, and Casper formation outcrops in the South Well Field area. This is an upper limit; actual recharge would be less because some water not evapotranspired runs off as surface flow. Huntoon and Lundy (1979) calculated recharge to the Casper Formation near Laramie, Wyoming, where the Casper Formation is lithologically similar and the climate is similar to that in the South Well Field area; they calculated a recharge rate of 1.4 inches, about 10 percent of average annual recharge, based on known discharge rates and the known outcrop area.

3.C WATER USE

The city of Douglas is the largest user of water from the Madison aquifer system in the vicinity of the South Well Field. The city obtains water from a spring issuing from alluvium overlying the Casper Formation in T. 32 N., R. 74 W., sec. 3dba. The spring has been used as a municipal water supply since 1923, when a spring house was constructed to collect all the discharge from the spring and a pipeline was laid to the city. All of the spring discharge is collected and diverted to the city of Douglas.

There are a few water wells completed in the Madison aquifer system north of the flanks of the Laramie Mountains; these are shown in Figure 3-10. Only two unused wells are completed in the Madison within a two-mile radius of the well field; these are the U.S. Geological Survey's observation well at the Barber Ranch (T. 32 N., R. 74 W., sec. 32ed), and an abandoned oil well (T. 33 N., R. 74 W., sec. 3). Only one well open to the Casper Formation is known to exist within a

Fig 3-10
Permitted Wells in Green Valley Area



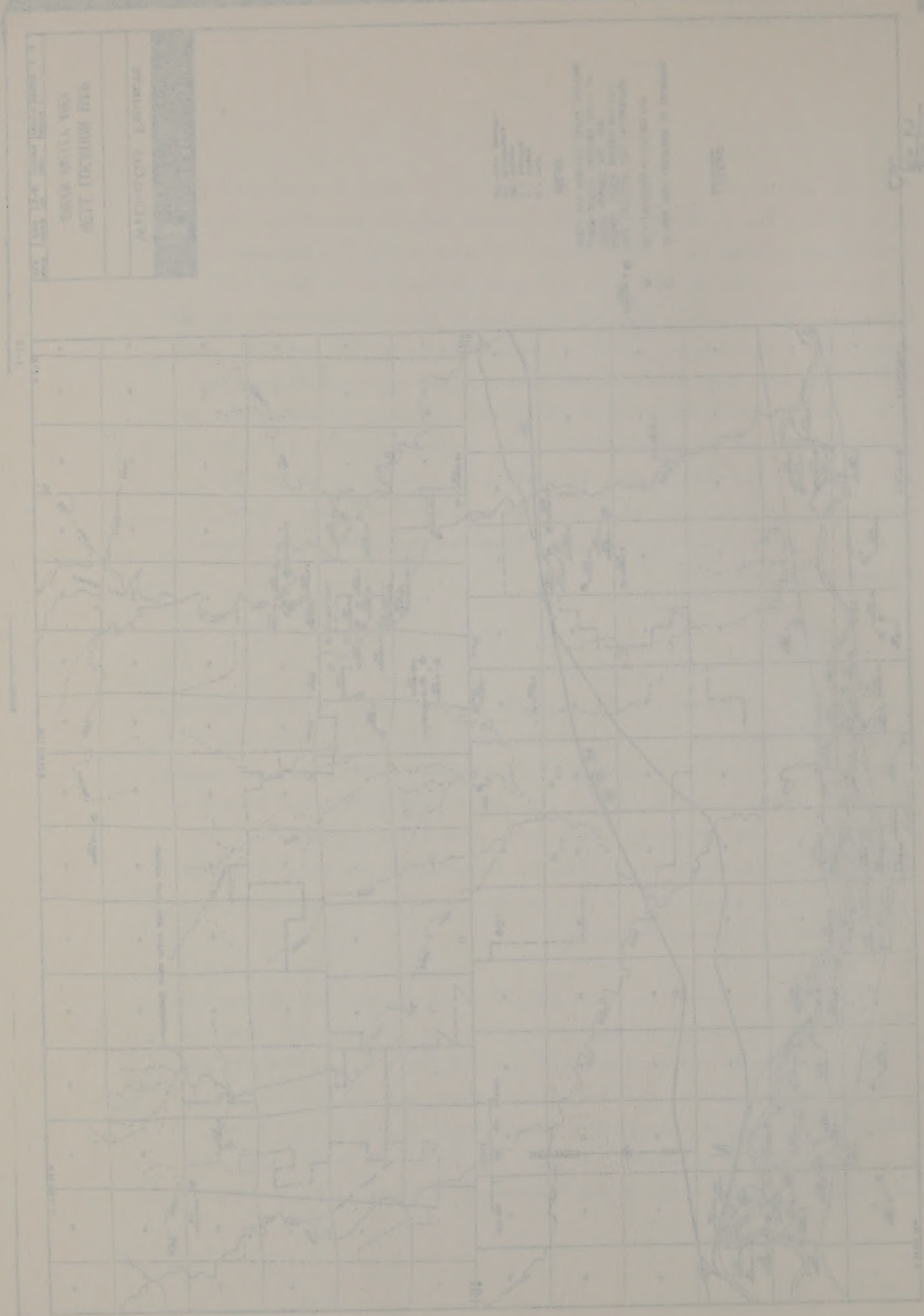
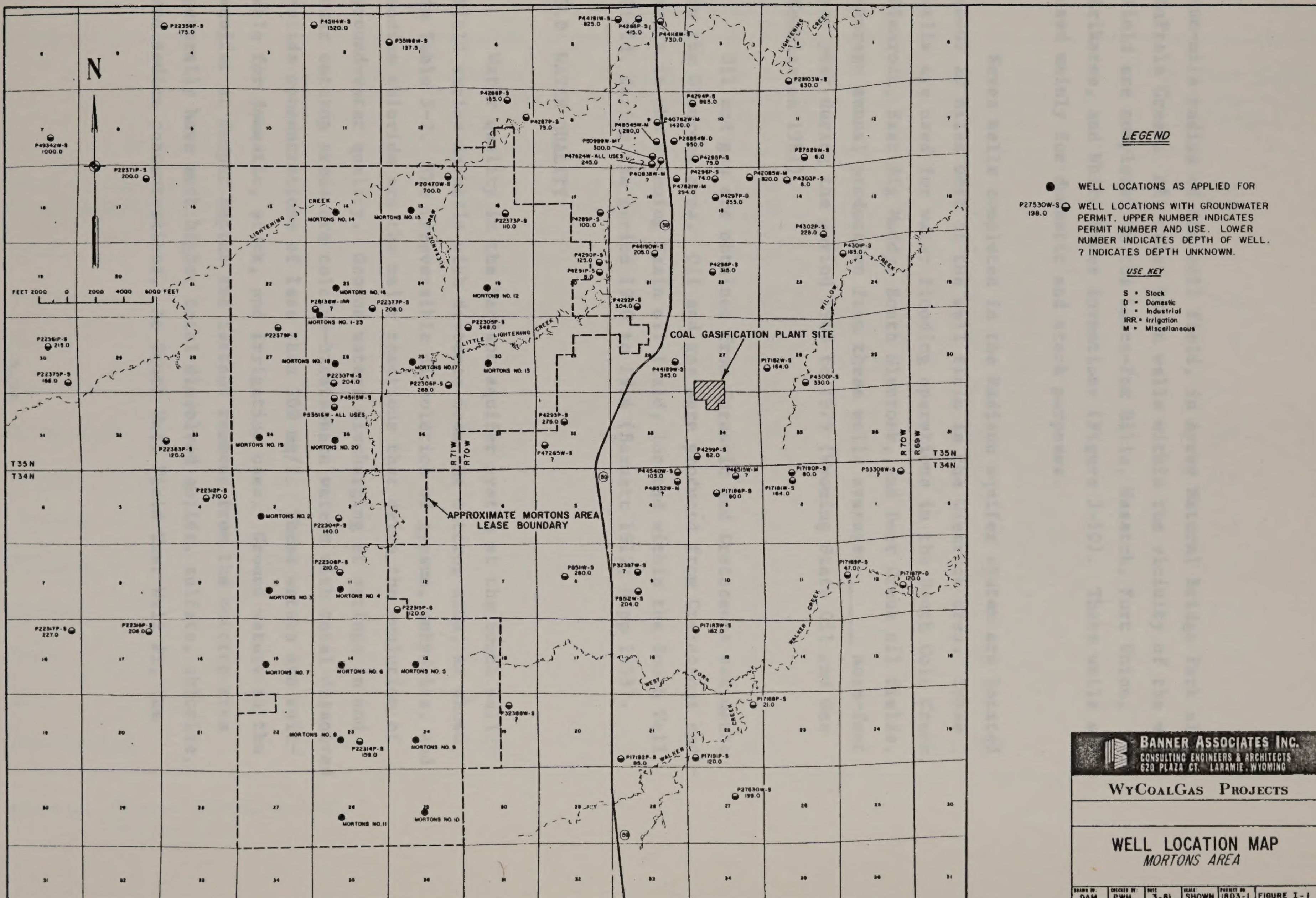


Fig 3-10
Permitted Wells
in Green Valley
Area

Fig 3-16 concluded
Permitted Wells in Mortons Area



I-2A

Fig 3-10
Excluded
Drilled wells
in Montana
Area

two-mile radius of the well field, in Ayres Natural Bridge Park along LaPrele Creek. All other known wells within the vicinity of the well field are completed in the Lance-Fox Hills, Wasatch, Fort Union, Arikaree, and White River formations (Figure 3-10). These wells are used mainly for domestic and stock purposes.

Seven wells completed in the Madison aquifer system are located about 20 miles west of the well field in the Glenrock area. These wells are used for water flooding operations in the South Cole Creek, Glenrock, East Big Muddy, South Glenrock, and Deer Creek oil fields. Average annual production from these wells averaged ______ acre-feet per year during the period 1969 to 1979 (Wyoming State Oil and Gas Commission 1981).

Oil and gas are obtained from Jurassic and Cretaceous sediments in the Glenrock area. Oil and gas were produced from Cretaceous sediments in the Brenning Basin oil field, located within the South Well Field, during the period 1900 to 1914 (Barnett 1912; Rapp 1953).

3.D WATER QUALITY

Water quality in the Madison aquifer system at the South Well Field varies markedly with distance from the outcrop area, as shown in Table 3-2. The irreversible dissolution of gypsum, anhydrite, and sodium chloride are the major reactions that drive the evolution of ground-water quality. Ground waters discharging at springs in and near outcrop areas are calcium-bicarbonate waters with total dissolved solids concentrations of less than 200 mg/l. These waters are suitable for domestic, stock, and irrigation uses. Ground waters in the aquifer at deeper depths and farther removed from the outcrop area generally have much higher total dissolved solids, sulfate, chloride, and sodium concentrations. At South Well Field Test Well #1, the

TABLE 3-2

GROUND WATER QUALITY - GREEN VALLEY WELL FIELD AREA

	Green Valley[a] Well # 1 33-73-32	Douglas[a] City Spring 32-74-3db	Continental Oil Company[b] Madison Water Flood Wells 33-75-20aac	33-75-8dbb	Flathead Springs[a] on Little Box Elder Cr. 32-74-17ba	Flathead Springs[a] on Cottonwood Cr. 32-74-23cb
Total Dissolved Solids	1,052	150	1,010	2,970	110	102
Total Hardness ($CaCO_3$)	--	230	514	1,230	160	110
Calcium	154	54	156	355	38	34
Magnesium	33	22	30	82	16	6.6
Sodium	129	11	103	488	6	7
Potassium	26	2	12	37	.8	1.7
Bicarbonate	195	240	124	95	200	140
Sulfate	520	35	512	1,370	3.3	6.6
Chloride	94	4	100	556	.7	1.1
Fluoride	--	.7	1.4	4.0	1.2	.6
Nitrate	--	3.7	.2	0.0	5	2.4
Boron	--	.01	110	710	.01	.02
Iron	--	--	--	--	--	--
Date Sampled	5/14/74	12/29/80	7/72	7/72	12/29/80	12/30/80

Sources: [a]Banner Associates 1981.
[b]Hodson 1974.

ground waters are a calcium sulfate type with total dissolved solids concentrations of about 1,050 mg/l; these waters are not suitable for domestic uses, as the EPA primary drinking water standards for total dissolved solids and sulfate are exceeded. Ground waters from Madison wells used for water flooding in the Glenrock area are a calcium-sulfate type with total dissolved solids concentrations ranging to over 3,000 mg/l (Hodson 1974); these wells are between 6,000 and 11,000 feet deep.

3.E METHOD USED TO CALCULATE IMPACTS

Sufficient surface water is expected to be available in most years to meet project requirements. During the 50 year period simulated in the operations studies for the project water supply system, surface water sources would not meet plant demands during only eight years, six of which would occur consecutively. Approximately 1,700 acre-feet/year of water would be required from other sources during these six years.

For purposes of illustration, a worst case scenario where approximately 2,000 acre-feet/year of water would be pumped from each aquifer system for 30 years was used to assess the potential impacts of project operation on ground waters. This scenario was selected for the following reasons:

- It is likely that approximately 4,000 acre-feet/year of water will be available to the project from LaPrele Reservoir.

- If it is assumed that no water is available for diversion from the North Platte River during the life of the project, average annual ground-water demands would be approximately 2,000 acre-feet.

- If it is assumed that no water will be available from the North Platte River, the maximum annual surface water deficit calculated for the project is less than 4,000 acre-feet (3,810 acre-feet).

- The operations studies suggest that there is a high probability that just less than 2,000 acre-feet/year of ground water will be needed to supply the project for up to six consecutive years.

3.F CALCULATED IMPACTS

The numerical model for simulating three-dimensional ground-water flow developed by Trescott and Larson (1976) was also used to estimate project impacts on the Madison aquifer. The South Well Field was modeled as a three layer aquifer system consisting of the Flathead and Madison formations, the Casper Formation, and Permian-, Jurassic- and Triassic-aged formations (upper layer). Overlying strata were assumed not to be in hydraulic connection with the formations in the system. The boundaries of the model, which were all specified as no flow boundaries, were defined as follows: the Flathead-Precambrian contact on the south, the western boundary of R. 75 W. on the west, the northern boundary of T. 34 N. on the north, and approximately the eastern boundary of R. 72 W. on the east (Table 3-3). Recharge was specified as occurring to the Madison and Casper formation outcrop areas from direct precipitation and runoff. Constant fluxes were specified in the area where Little Box Elder Creek and Cottonwood Creek cross the Madison Formation outcrops. The Casper Formation adjacent to the LaPrele Reservoir, at Douglas City Springs, along LaPrele Creek, and along Box Elder Creek, and the Madison Formation along Box Elder Creek were modeled as constant heads, with the specified head equal to elevation (Table 3-4).

TABLE 3-3
BOUNDARY CONDITIONS USED IN THE MODEL OF THE SOUTH WELL FIELD

Boundary	Location	Type	Comment
Southern	Flathead-Precambrian contact	no-flow	Precambrian rocks are impermeable relative to the Flathead, Madison and Casper formations
Northern	approximately the northern boundry of T 34 N	no-flow	Potentiometric data suggest that a zone of very low transmissivity separates the Madison aquifer system along Laramie Mountains from that in Powder River Basin (refer to Section 2.4). Detailed geologic mapping south of North Platte River found no evidence for a structural discontinuity in this region. Therefore zone of no-flow placed north of North Platte River. Calculated impacts relative insensitive to this boundary.
eastern	approximately eastern boundary of R 72 W	no-flow	The aquifer is apparently continuous to the east: the boundary was placed in this location because significant drawdowns did not extend beyond this point.
western	approximately the western boundary of R 75 W	no-flow	The boundary was placed at this point because of the complex structural geology in this area.

An attempt was made to model known steady state conditions in the aquifer system. However, since existing potentials in the aquifers are poorly known, no real model calibration could be obtained. Model parameters were then varied within the ranges presented in Table 3-5. Parameter combinations which reasonably simulated the existing potentiometric surface under steady state conditions were used to model aquifer response to project-related withdrawals. These simulations were assumed to define the range of probable impacts from pumping.

The results of the modeling suggest that after six years of continuous pumping from the Madison aquifer at the rate of 2.82 cfs, flow at the Douglas City Spring will decrease by 15 to 30 percent, spring discharges to Box Elder Creek will decline by 0.2 to 0.35 cfs, and spring discharge to lower LaPrele Creek will decline by 0.25 to 0.5 cfs (Figures 3-11 through 3-13). These are the maximum impacts that are likely to occur during the life of the project. Continuous pumping at a rate of 2.82 cfs for 30 years was calculated to cause flow reductions of 35 to 40 percent at the Douglas City Spring, 0.5 to 1.0 cfs in Box Elder Creek, and 0.75 to 1.0 cfs in LaPrele Creek. Continuous pumping from the well field for a 30-year period was calculated to have only a very small probability of significantly affecting water levels in any wells now used for domestic, stock, and irrigation purposes, or of significantly affecting flows in any other springs or streams.

TABLE 3-4
RANGE OF PARAMETER VALUES USED IN THE MODEL OF THE SOUTH WELL FIELD

Layer	Transmissivity ft/sec	Confined Storage Coefficient[a]	Leakage Coefficient	Recharge Rate to outcrop areas	Constant Fluxes	Constant Heads	Pumping Rate (cfs)
Madison-Flathead	.003 - .006[b]	10^{-4}		1.4 - 3.5	1.2 cfs Little Box Elder Cr. 0.5 cfs Cottonwood Cr.	5280' in valley of Box Elder Cr.	2.86
			10^{-8} - 10^{-11}				
Casper	.003 - .015	10^{-4}		1.4 - 3.5	-	5270 in LaPrele Creek Valley 5220 in Box Elder Creek Valley 5270-5280 Douglas City Springs 5410 LaPrele Reservoir	0
Upper	.0005	10^{-4}	10^{-13}	0	-	-	0

[a] Storage coefficient in outcrop areas was specified as 0.1.

[b] The transmissivity of the Madison-Flathead layer in the outcrop area and within two miles of the outcrop area was specified as being 1 to 10 times greater than the transmissivity elsewhere in the Madison layer.

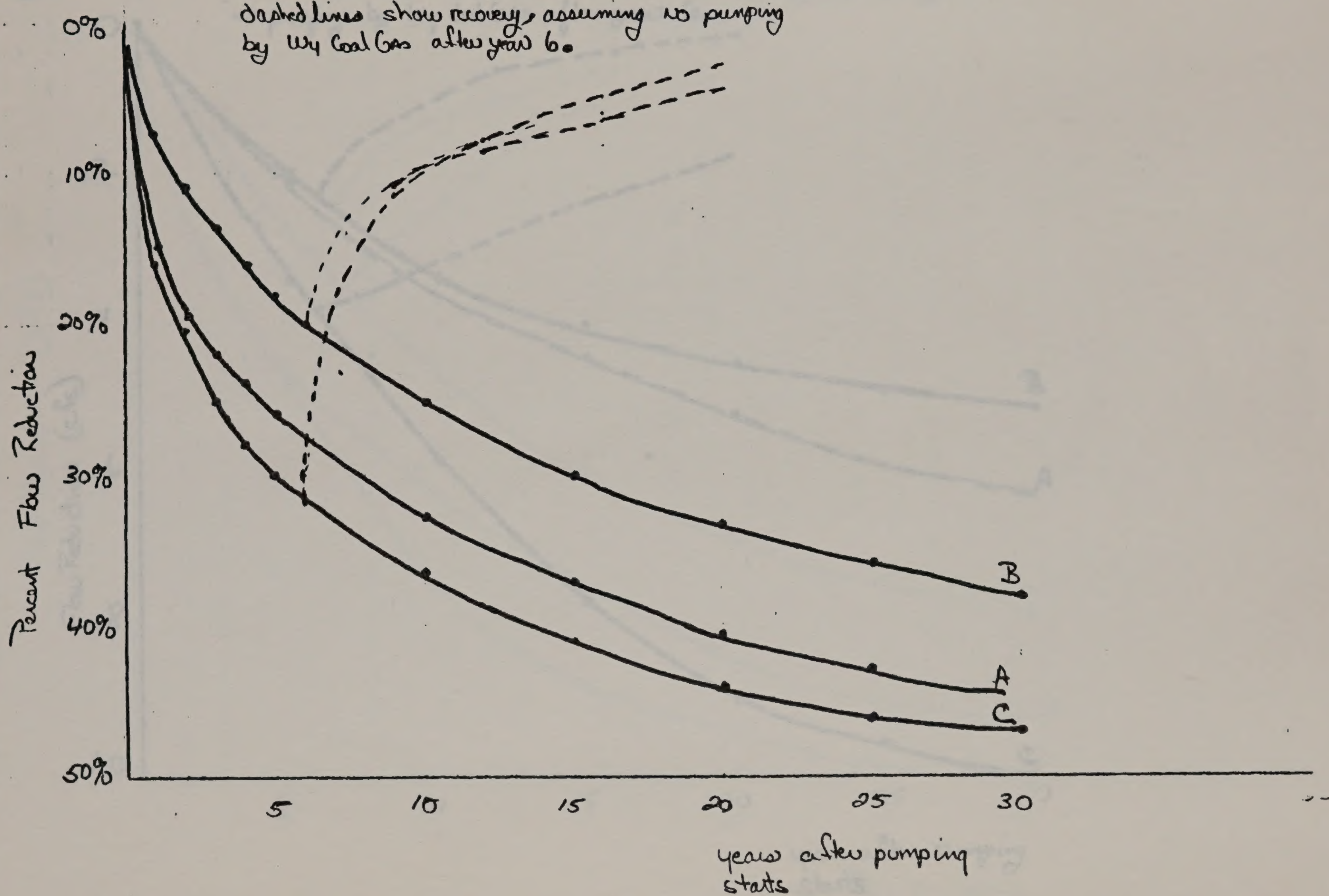
TABLE 3-5
PARAMETER VALUES USED IN MODELS OF THE SOUTH WELL FIELD[a]

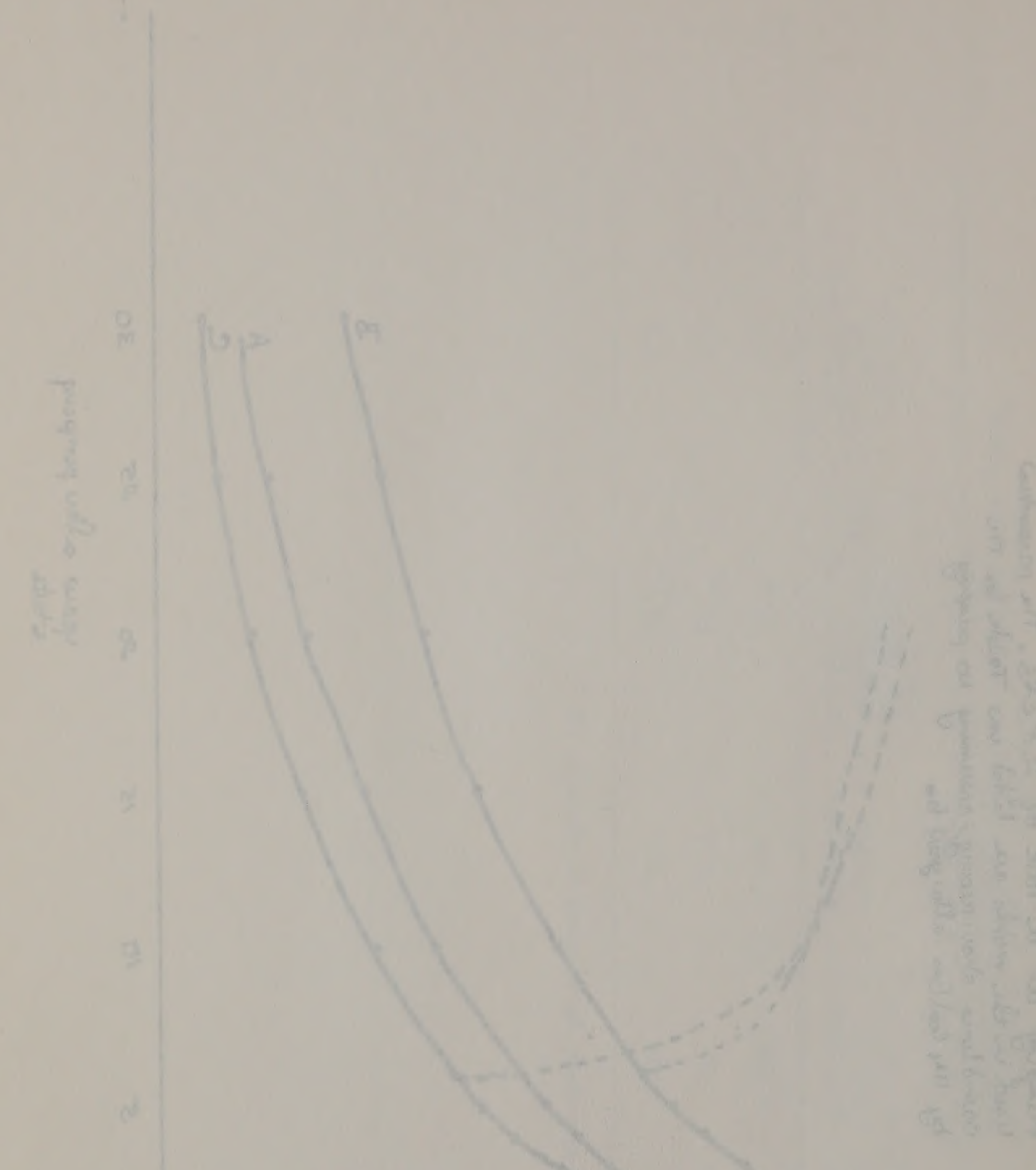
Run	Transmissivity (ft/sec) Madison Formation Outcrop	Transmissivity (ft/sec) Madison Formation Elsewhere	Transmissivity (ft/sec) Casper Formation	Leakage Coefficient between Madison and Casper Formations (sec^{-1})	Recharge Rate (inches/year)
A	.03	.003	.003	10^{-9}	1.4
B	.016	.004	.015	10^{-10}	3.5
C	.016	.004	.015	10^{-11}	3.5

[a]Model results are shown in Figures 10 through 12.

I-10

Figure 3-11. Calculated Range of Probable Flow Reductions at Douglas City Springs with Wy Coal Gas Pumping at a rate of 2.8 cfs. The parameters used in the models are listed in Table 6. The dashed lines show recovery, assuming no pumping by Wy Coal Gas after year 6.





I-11

Figure 3-12. Range of Calculated Flow Reductions in Box Elder Creek Below the Paleozoic outcrops with Wy Coal Gas pumping at a rate of 2.8 cfs. The parameters used in the models are listed in Table 6. The dashed lines show recovery, assuming no pumping by Wy Coal Gas after year 6.

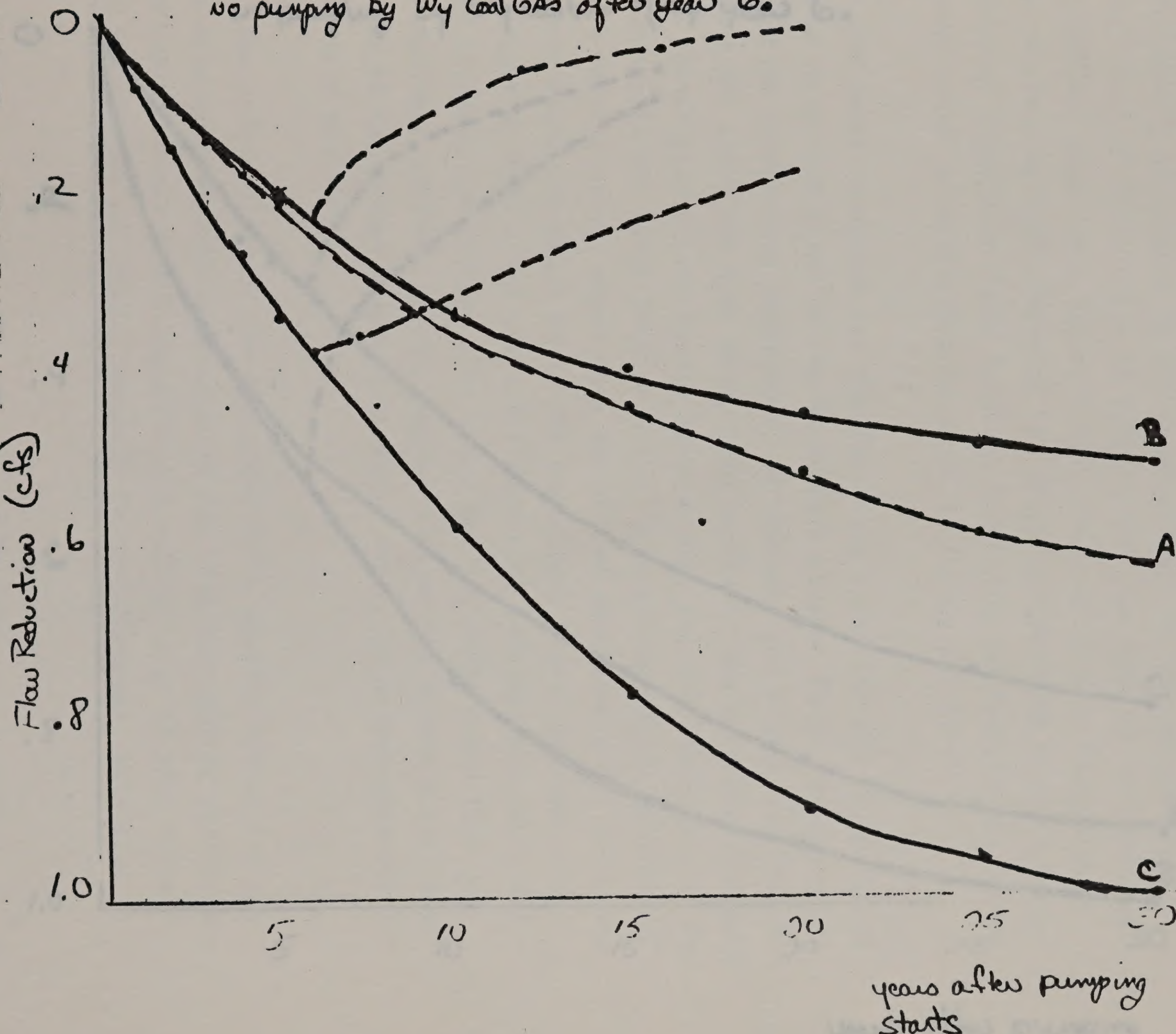
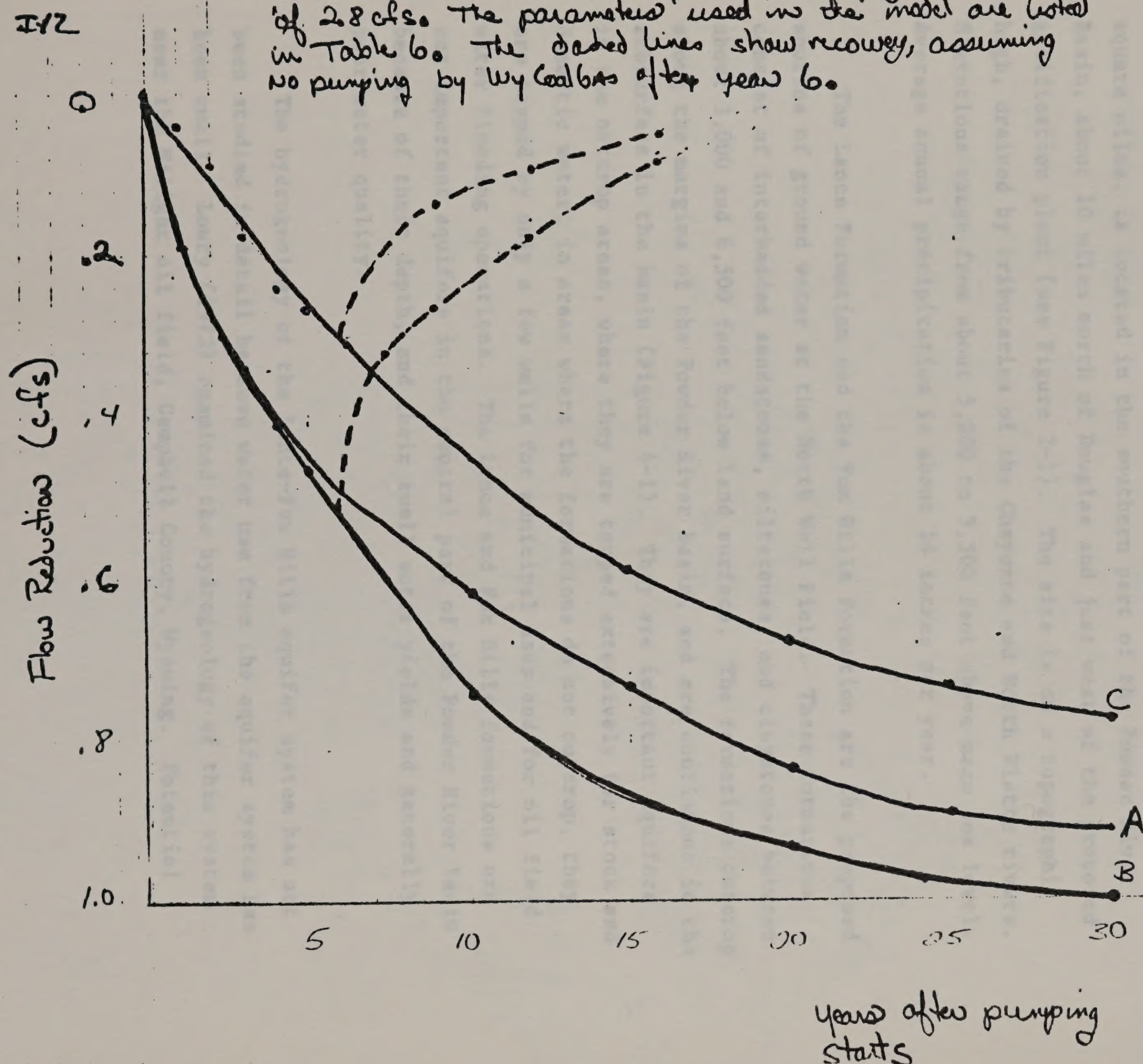


Figure 3-13. Range of calculated Flow Reductions in LaPrele Creek below the reservoir with Wy Coal Gas pumping at a rate of 2.8 cfs. The parameters used in the model are listed in Table 6. The dashed lines show recovery, assuming no pumping by Wy Coal Gas after year 6.



Chapter 4
NORTH WELL FIELD

4.A INTRODUCTION

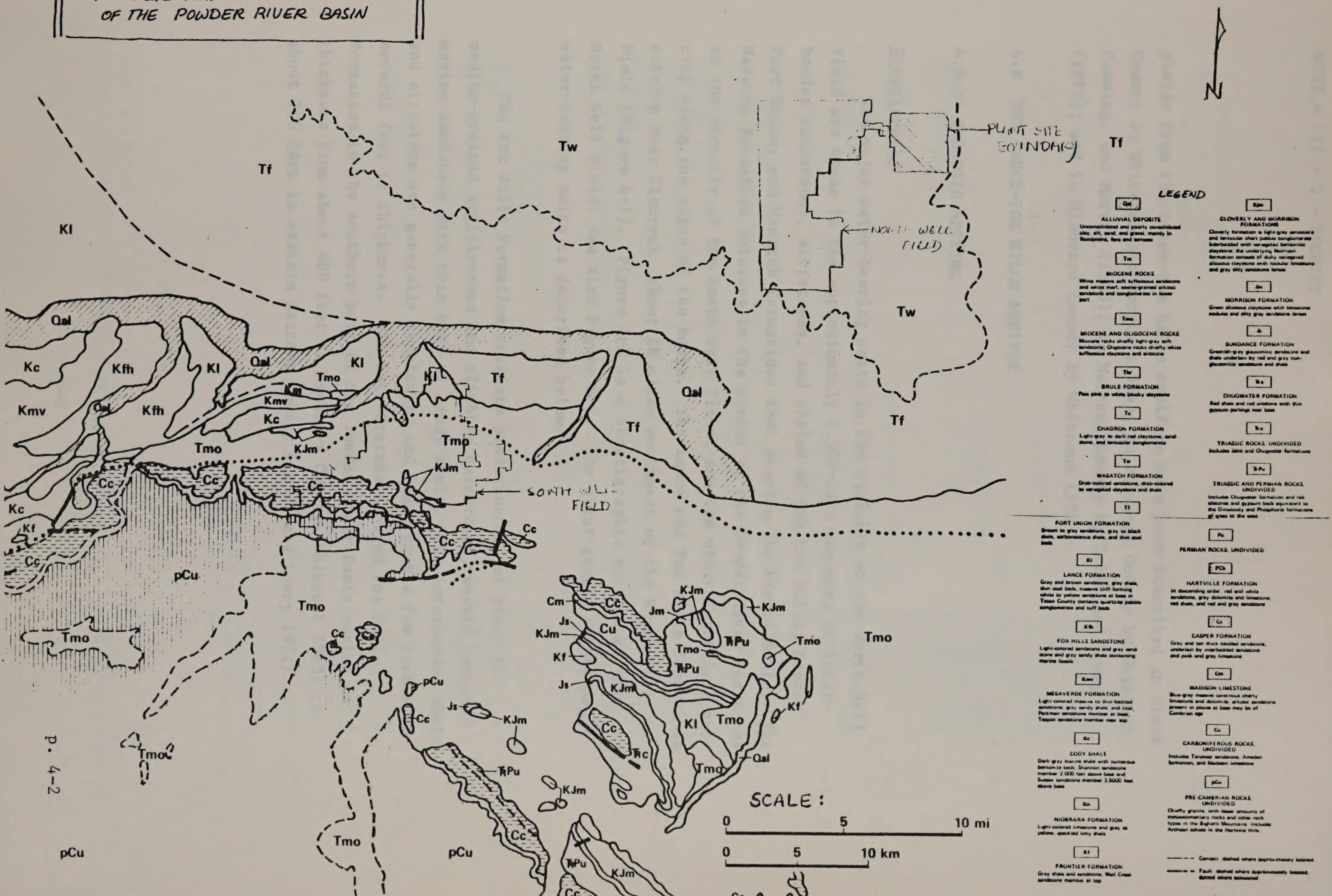
The North Well Field, which encompasses an area of about 30 square miles, is located in the southern part of the Powder River Basin, about 10 miles north of Douglas and just west of the proposed gasification plant (see Figure 2-1). The site is on a topographic high, drained by tributaries of the Cheyenne and North Platte rivers. Elevations range from about 5,200 to 5,500 feet above mean sea level. Average annual precipitation is about 14 inches per year.

The Lance Formation and the Fox Hills Formation are the proposed sources of ground water at the North Well Field. These formations consist of interbedded sandstones, siltstones, and claystones between about 3,000 and 6,500 feet below land surface. The formations outcrop along the margins of the Powder River Basin, and are continuous in the subsurface in the basin (Figure 4-1). They are important aquifers in the outcrop areas, where they are tapped extensively for stock and domestic water; in areas where the formations do not outcrop, they are tapped by only a few wells for municipal uses and for oil field water flooding operations. The Lance and Fox Hills formations are not important aquifers in the central part of the Powder River Basin because of their depth, and their small water yields and generally poor water quality.

The hydrogeology of the Lance-Fox Hills aquifer system has not been studied in detail because water use from the aquifer system has been small. Lowry (1972) examined the hydrogeology of this system near the Hilight oil field, Campbell County, Wyoming. Potential

FIGURE 4-1

GEOLOGIC MAP OF SOUTHERN PART
OF THE POWDER RIVER BASIN



605 76C - 21BA

yields from the Lance-Fox Hills aquifers have been described in Crook County by Whitcomb and Morris (1964); in Johnston County by Whitcomb, Cumming, and Morris (1965); in Natrona County by Crist and Lowry (1972); and in Niobrara County by Whitcomb (1965).

4.B THE LANCE-FOX HILLS AQUIFER

4.B.1 GEOLOGIC SETTING

Stratigraphy

The major water-bearing units in the vicinity of the North Well Field are those in the approximately 6,500-foot sequence of interbedded sandstones, siltstones, and shales of the Fox Hills, Lance, Fort Union, and Wasatch formations that overlie the Pierre Shale. The Wasatch Formation outcrops in the center of the Powder River Basin and in the vicinity of the North Well Field, and the other formations outcrop along the edges of the basin. The Lance and Fox Hills formations outcrop near Glenrock, about 18 miles southwest of the North Well Field (Figure 4-1). Figure 4-2 is a stratigraphic section at the North Well Field; see also Figure 3-2. The stratigraphy of the major water-bearing units is described below.

The Fox Hills Formation consists predominately of fine- to medium-grained argillaceous and slightly calcareous, weakly cemented marine sandstone with thin beds of sandy shale. The interbedded shale and siltstone are generally lenticular and range from a few inches to several feet in thickness. The Late-Cretaceous-aged Fox Hills Formation in the southern part of the Powder River Basin varies in thickness from about 400 feet in Niobrara County (Whitcomb 1965) to about 700 feet in eastern Natrona County (Crist and Lowry 1972).

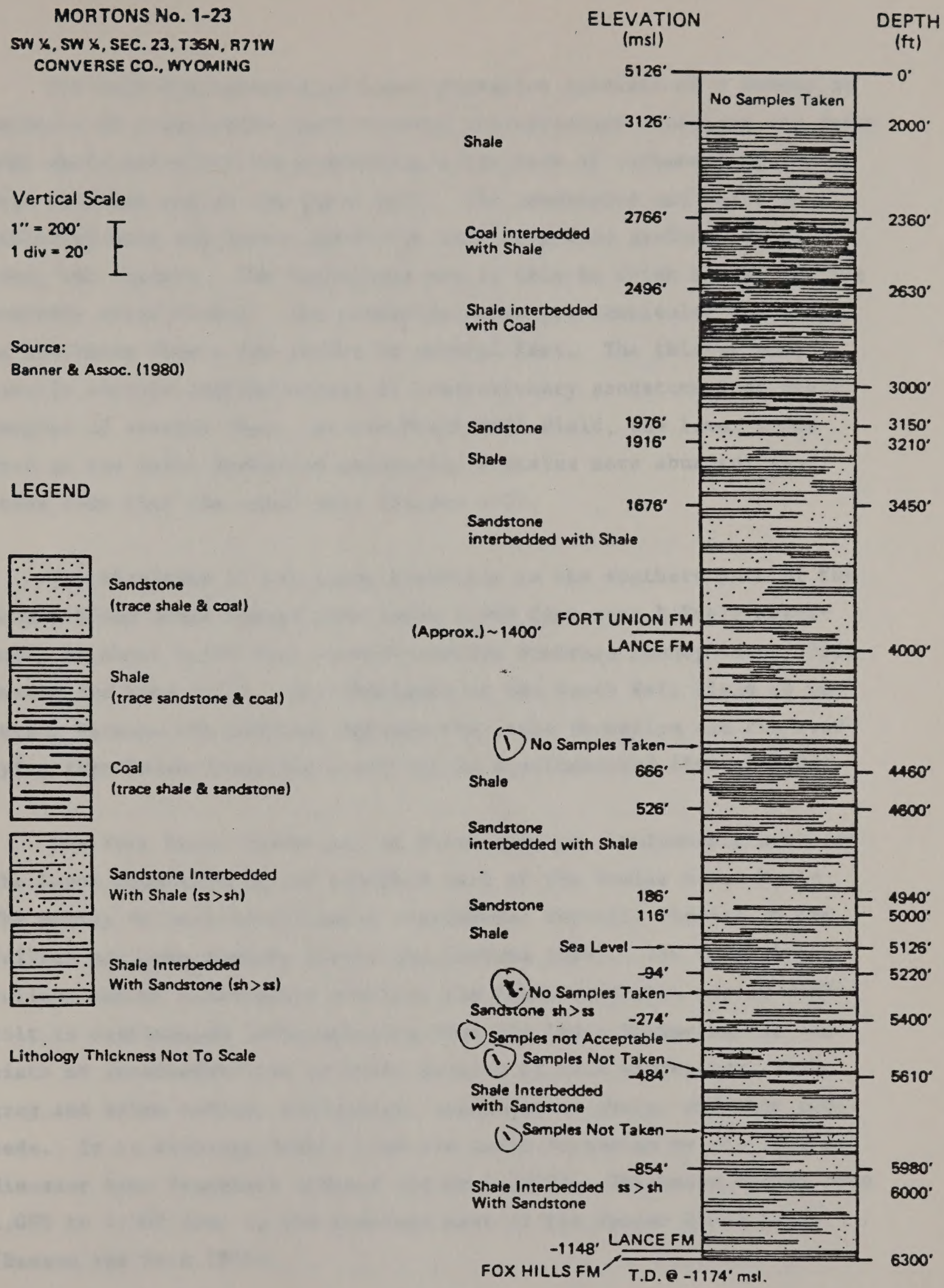


FIGURE ~~2.3.2.-14~~
STRATIGRAPHIC COLUMN IN THE NORTH WELL FIELD

The Late-Cretaceous-aged Lance Formation consists of a nonmarine sequence of interbedded light-colored concretionary sandstone and dark-gray shale and siltstone containing a few beds of carbonaceous shale near the base and in the upper part. The sandstones are white to yellowish gray and brown, generally fine to medium grained, calcareous, and friable. The sandstones may be thin to thick bedded and are commonly cross bedded. The sandstone units are lenticular and range in thickness from a few inches to several feet. The thicker beds locally contain loglike masses of concretionary sandstone that reach lengths of several feet. At the North Well Field, the lower 2,000 feet of the Lance Formation apparently contains more abundant sandstone beds than the upper part (Figure 4-2).

The thickness of the Lance Formation in the southern part of the Powder River Basin ranges from about 3,000 feet near LaPrele Reservoir, to about 2,300 feet in northeastern Niobrara County (Rapp 1953; Denson and Horn 1975). Its thickness at the North Well Field is unknown, because the contrast between the Lance Formation and the overlying Fort Union Formation could not be distinguished (Banner 1980).

The Fort Union Formation, of Paleocene age, conformably overlies the Lance Formation in the southern part of the Powder River Basin. The poorly to semi-consolidated continental deposits consist of the Tullock and Lebo members (Sharp and Gibbons 1964). The lower-lying Tullock Member conformably overlies the Lance Formation and is difficult to distinguish lithologically from the Lance Formation. It consists of interbedded tan to buff, massive to thin sandstones, dark gray and brown shales, siltstones, carbonaceous shale, and thin coal beds. It is distinguishable from the Lance Formation by its lack of dinosaur bone fragments (Denson and Horn 1975). Thickness varies from 1,000 to 1,500 feet in the southern part of the Powder River Basin (Denson and Horn 1975).

The Lebo Member of the Fort Union Formation conformably overlies the Tullock Member. The Lebo Member consists of light to dark gray, very fine grained to conglomeritic sandstone interbedded with varying amounts of siltstone, claystone, carbonaceous shale, brown ironstone lentils, and coal. The deposits are all of fluviatile and paludal origin. The drab appearance and massive sandstones of the Tullock distinguish it easily from the Lebo Member, which generally has a predominance of siltstone and shale. The thickness of the Lebo Member varies from 1,700 to 2,800 feet in the southern part of the Powder River Basin (Denson and Horn 1975).

The Eocene-age Wasatch Formation, which outcrops over most of the central part of the Powder River Basin and outcrops at the North Well Field, unconformably overlies the Fort Union Formation. In the southern part of the Powder River Basin, it consists of semiconsolidated clay and siltstone containing thick lenses of coarse, cross-bedded arkosic sandstones and thin beds of coal or a carbonaceous shale. The gray weathering siltstone and claystone are moderately compacted, whereas the sandstone beds are generally friable. The Wasatch Formation deposits are up to 1,000 feet thick in the southern part of the Powder River Basin.

The hydraulic conductivities of the strata in the Fox Hills, Lance, Fort Union, and Wasatch formations are extremely variable. A range of hydraulic conductivities from 0.7 to 25 gal/day/ft^2 for these units in the Powder River Basin was reported in the Eastern Powder River Coal EIS (BLM 1979). The Lance-Fox Hills Formation at the North Well Field well no. 1-23 (T. 35 N., R. 71 W., sec. 23) was calculated to have an average hydraulic conductivity of about 0.25 gal/day/ft^2 over a 2,088-foot section from pump test data (refer to Appendix B). The Tullock Member of the Fort Union Formation in T. 36 N., R. 75 W., sec. 25, was calculated from pump test data to have a hydraulic conductivity of about 20 gal/day/ft^2 (Kerr-McGee 1977).

The sequence from the Fox Hills Formation to the Wasatch Formation is underlain by a 5,000- to 6,000-foot sequence of Cretaceous-age marine sediments, predominately composed of dark gray and black shale, and containing minor amounts of interbedded shaly sandstone and limestone (Figure 4-2). These marine deposits comprise, in ascending order, the Skull Creek Shale, Newcastle Sandstone, Mowry Shale, Belle Fourche Shale, Greenhorn Formation, Carlile Shale, Niobrara Formation, and Pierre Shale. Small supplies of water can be obtained from wells tapping selected intervals in this sequence, but generally the deposits in this interval have very low permeabilities.

Geologic Structure

The North Well Field is located only a few miles northeast of the axis of the Powder River Basin; see Figures 3-5 and 4-3. Structural relief in the vicinity of the well field is slight; dips are less than 3 degrees. South of the well field, along the margins of the basin, the Lance and Fox Hills formations dip basinward as much as 20 degrees. No major fault zones are known to occur near the well field.

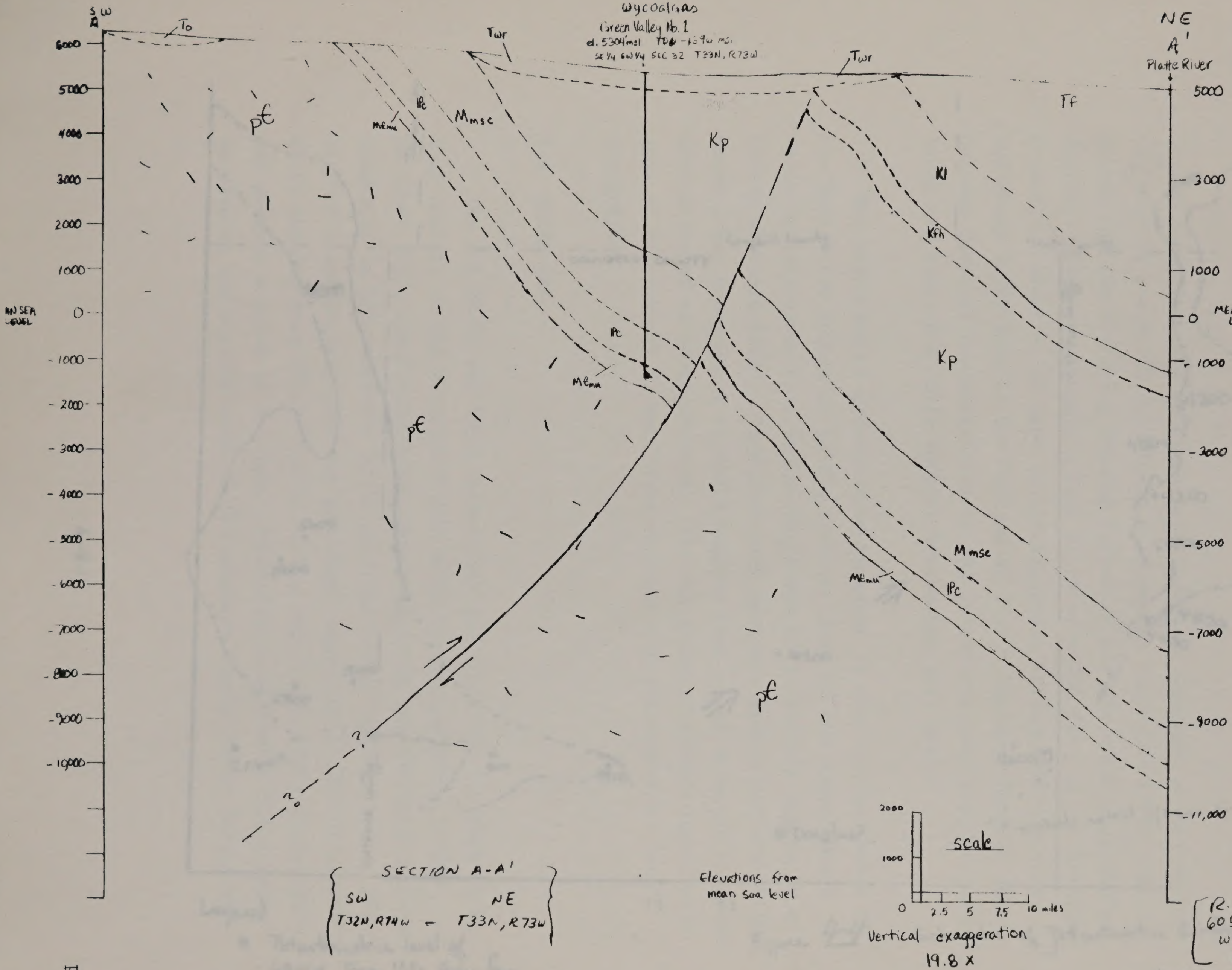
4.B.2 GROUND-WATER MOVEMENT

The potentiometric surface of the Lance-Fox Hills aquifer system in the southern part of the Powder River Basin is poorly defined because of limited data (Figure 4-4). The available data suggest that water recharges the aquifer system in outcrop areas along the southwestern margins of the Powder River Basin and flows northeast, discharging at the outcrop areas in Niobrara County. Potentiometric gradients between the outcrop area and the North Well Field average in the range of 10 to 30 feet per mile.

Total ground-water flow in the system is not large. Based on an average hydraulic conductivity of 0.25 gallons per day per square foot and a porosity of 0.15, flow in the aquifer system in the vicinity of

Fig 4-5

STRUCTURAL SECTION A-A' OF GREEN VALLEY AREA



LEGEND

To	Ogallala Fm (Pliocene)
Twr	White River Fm (Oligocene)
Tf	Fort Union Fm (Paleocene)
Kl	Lance Fm (upper Cretaceous)
Kfh	Fox Hills Fm (upper Cretaceous)
Kp	Pierre Fm & Cretaceous shales undifferentiated
Mmsc	Mesozoic sedimentary rocks undifferentiated (morrison, 'Sundance,' chugwater Fms)
IPc	Permian Casper Fm.
MЄmu	Mississippian Madison Limestone and Cambrian rocks undifferentiated
pЄ	Granitic and metamorphic rocks

Sources:

PETROLEUM INFORMATION (1980)
DENSON, N.M. and HORN, G.N. (1975)

SECTION A-A'
SW — NE
T32N, R74W — T33N, R73W

R. CASIAS
60576C-2170
WYCOALGAS
March 1981

REVISED 7/81 RCC

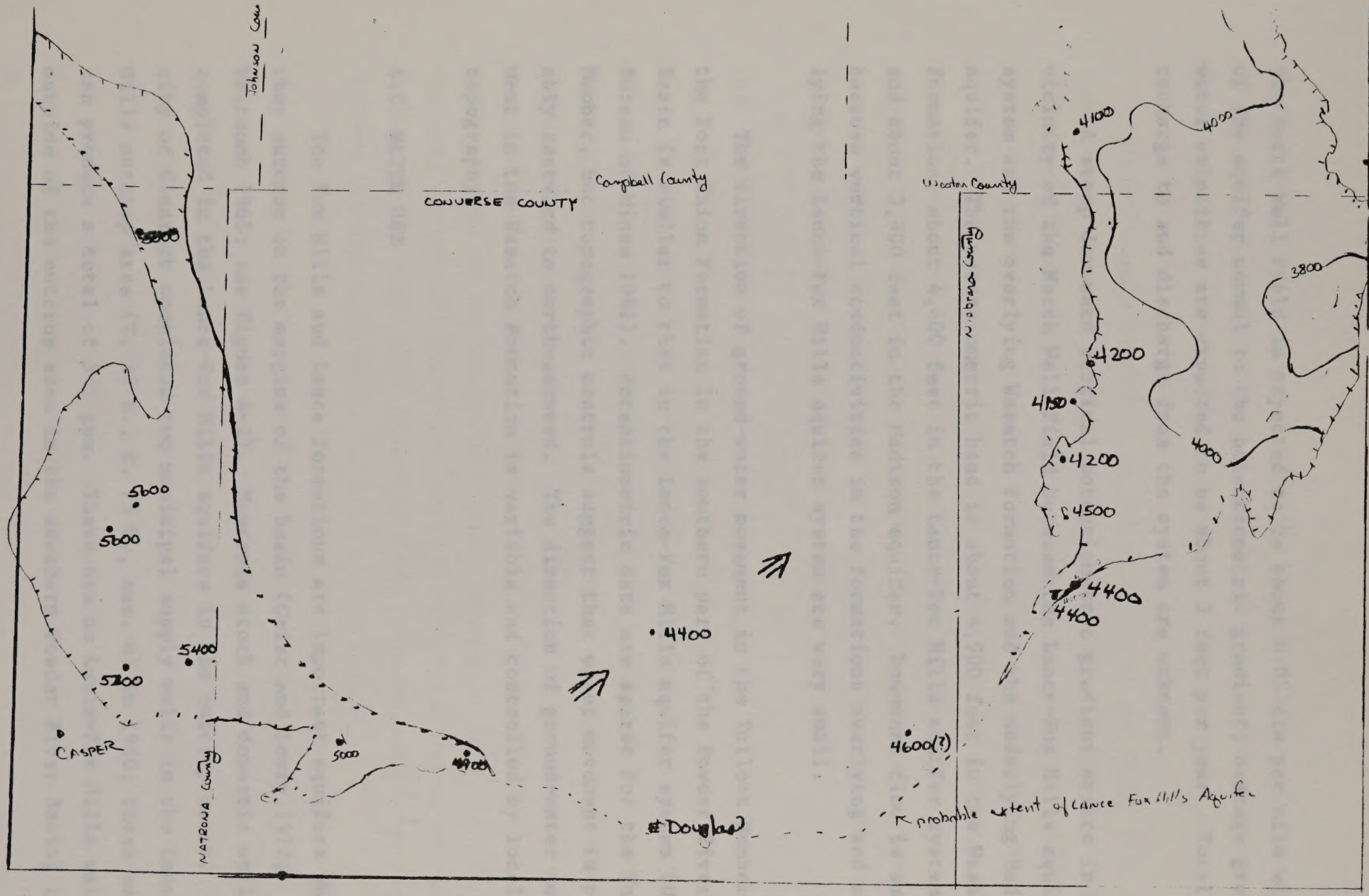


Figure 4-4 Schematic of Potentiometric Surface in LANCE - Fox Hills Formation

Scale : 1:500,000

Legend

- • Potentiometric level of LANCE Fox-Hills Aquifer
- outcrop area of LANCE Fox-Hills Formations
- 4100 - contour lines on potentiometric surface

the North Well Field is expected to be about 0.03 cfs per mile width of the aquifer normal to the potentiometric gradient; average ground-water velocities are expected to be about 3 feet per year. Total recharge to and discharge from the system are unknown.

A steep downward vertical potentiometric gradient exists in the vicinity of the North Well Field between the Lance-Fox Hills aquifer system and the overlying Wasatch Formation and the underlying Madison aquifer. The potentiometric head is about 4,900 feet in the Wasatch Formation, about 4,400 feet in the Lance-Fox Hills aquifer system, and about 3,800 feet in the Madison aquifer. Downward flow is small because vertical conductivities in the formations overlying and underlying the Lance-Fox Hills aquifer system are very small.

The direction of ground-water movement in the Tullock Member of the Fort Union Formation in the southern part of the Powder River Basin is similar to that in the Lance-Fox Hills aquifer system (U.S. Bureau of Mines 1981). Potentiometric data are sparse for the Tullock Member, but topographic controls suggest that water movement is probably eastward to northeastward. The direction of ground-water movement in the Wasatch Formation is variable and controlled by local topography.

4.C WATER USE

The Fox Hills and Lance formations are important aquifers where they outcrop on the margins of the basin (Crist and Lowry 1972; Whitcomb 1965; see Figure 4-2). Numerous stock and domestic wells are completed in the Lance-Fox Hills aquifers in the outcrop areas. The city of Glenrock completed two municipal supply wells in the Lance-Fox Hills outcrop area (T. 33 N., R. 75 W., sec. 4) in 1980; these wells can produce a total of 345 gpm. There are no Lance-Fox Hills wells outside of the outcrop area in the southern Powder River Basin; the

nearest deep Lance-Fox Hills wells are in the Hilight oil field, about 60 miles north of the North Well Field. The six wells in the Hilight field can produce about 500 gpm for water flooding operations.

Domestic and stock wells in the vicinity of the North Well Field generally produce water from outcrops of the Wasatch and Fort Union formations (Figure 3-11). A few deep wells are completed in the Fort Union Formation in the area where the Wasatch Formation outcrops. Water yields are generally less than 100 gpm, but some wells yield considerably more. Most of the deeper wells in the area were drilled as exploratory oil wells and subsequently turned over to ranchers (Wester 1981). The wells in T. 36 N., R. 72 W., sec. 28 are associated with Exxon's Highland Uranium Mine.

4.D WATER QUALITY

Ground water in the Lance-Fox Hills aquifer at the North Well Field is a sodium-bicarbonate water with a total dissolved solids concentration of about 600 mg/l (Table 4-1). Calcium, magnesium, and sulfate concentrations are very low. Total dissolved solids concentrations exceed the EPA's secondary drinking water standard of 500 mg/l. Ground waters in the Fort Union and Wasatch formations in the vicinity of the well field are generally sodium-calcium-bicarbonate-sulfate waters with total dissolved solids concentrations ranging between 235 and 1,340 mg/l.

Waters in the Lance-Fox Hills aquifers in the outcrop areas in Niobrara County range in total dissolved solids content from 1,040 to 3,250 mg/l (Table 4-2). The waters are all a sodium-bicarbonate or sodium-bicarbonate-sulfate type. They do not meet EPA's secondary drinking water standard for total dissolved solids; most do not meet the sulfate standard; and they are generally unsuitable for irrigation because of high sodium concentrations.

TABLE 4-1

WATER QUALITY IN WATER WELLS LOCATED IN VICINITY OF WYCOALGAS PLANT SITE[a] AND IN THE VICINITY OF THE NORTH WELL FIELD[b]

Location		Formation	Well Depth	Sample Date	Ca	Mg	Na	K	HCO_3	SO_4	Cl	F	B(g/l)	SiO_2	TDS(cal)	pH	°C
T. 34 N., R. 69 W., sec. 10dd	about 6 miles east of plant site	Fort Union Lebo Member	206	06-05-69	151	64	120	10	178	725	3.1	0.2	0	6.8	1170	8.0	12.0
T. 34 N., R. 68 W., sec. 9ddd	about 11 miles east of plant site	Fort Union Lebo Member	190	06-04-69	55	34	224	10	220	575	1.9	0.2	40	7.6	1030	7.7	12.0
T. 34 N., R. 68 W., sec. 12bbd	about 14 miles east of plant site	Fort Union Lebo Member	200	06-05-69	32	12	68	7.6	252	70	3.4	0.7	20	7.8	326	8.1	13.0
T. 36 N., R. 69 W., sec. 24dd	about 11 miles north-east of plant site about 4 miles south-west of well field	Fort Union Lebo Member Fort Union Lebo Member	434 210	06-05-69	4.6	3.0	134	2.8	246	102	2.2	0.8	20	7.9	384	8.1	13.0
T. 36 N., R. 70 W., sec. 9ccb	about 12 miles north-of plant site	Wasatch Formation	217	06-03-68	93	29	304	4.0	301	745	8.5	0.7	50	11	1340	7.6	12.0
T. 36 N., R. 72 W., sec. 9dd	about 6 miles north-west of well field	Wasatch Formation	212	06-06-69	36	8.5	146	2.4	184	278	5.0	0.3	10	11	577	7.7	11.0
T. 36 N., R. 72 W., sec. 29ba	about 7 miles north-west of well field	Wasatch Formation	400	07-22-69	45	7.0	94	6.0	220	160	4.0	-	-	-	424	6.6	-
T. 36 N., R. 73 W., sec. 27ba	about 12 miles north-west of well field	Wasatch Formation	180	06-06-69	69	15	53	5.7	260	136	3.8	0.3	20	15	235	7.7	10.0
T. 35 N., R. 71 W., sec. 23	well field test well	Lance-Fox Hills	6,300	02-25-75	3	1	247	5	610	23	22				601	8.0	58.0

Source: Hodson 1971.

[a]The WyCoalGas plant site is located in T. 35 N., R. 70 W., secs. 27 and 34.

[b]The North Well Field is located in T. 35 N., R. 71 W., secs. 13, 14, 15, 22-27, 34-36; T. 34 N., R. 71 W., secs. 1-3, 10-15, 22-27; T. 34 N., R. 70 W., secs. 18, 19; T. 35 N., R. 70 W., secs. 7, 17-20, 28-32.

TABLE 4-2

WATER QUALITY IN THE LANCE-FOX HILLS AQUIFERS IN OUTCROP AREAS IN SOUTHERN PART OF POWDER RIVER BASIN

Location	Formation	Well Depth	Sample Date	Ca	Mg	Na	K	HCO_3	SO_4	Cl	F	SiO_2	TDS(cal)
Niobrara County													
T. 37 N., R. 63 W., sec. 13cb	Fox Hills	300	12-1-59	46	37	325	4	528	543	9	.2	12	1,240
T. 38 N., R. 62 W., sec. 17aa	Fox Hills	110	12-1-59	14	3.2	1,040	3	380	1,970	23	.6	8	3,250
T. 38 N., R. 63 W., sec. 23dc	Fox Hills	105		37	13	598	5	380	1,120	11	.3	10	1,980
T. 36 N., R. 65 W., sec. 14db	Lance	73	12-2-59	89	30	221	12	384	393	80	.5	15	1,030
T. 37 N., R. 65 W., sec. 7bb	Lance	128	12-2-59	12	1.5	432	2	515	523	6.7	1.5	7	1,250
T. 38 N., R. 63 W., sec. 30cc	Lance	70	12-1-59	99	32	301	8	548	553	9.9	.8	22	1,300
T. 39 N., R. 65 W., sec. 21cc	Lance	280	12-1-59	47	3.5	922	4	676	1,500	15	.2	17	2,850
T. 39 N., R. 65 W., sec. 21dc	Lance	250	12-1-59	29	11	574	3	666	752	7.4	.4	20	1,730
T. 40 N., R. 63 W., sec. 33bb	Lance	400	12-1-59	4.5	.2	596	2	1,370	0.3	110	5.4	10	1,400
T. 40 N., R. 64 W., sec. 1aa	Lance	112	12-1-59	13	2.6	675	2	1,050	611	6.5	.7	10	1,840
Converse County													
T. 33 N., R. 75 W., sec. 4	Lance		05-27-80	8	3	606	6	537	756	36			1,727

Sources: Whitcomb (1965); Brogan (1981).

4.E IMPACTS OF PUMPING

The impacts that would occur as a result of pumping from the proposed North Well Field were calculated by numerically modeling the Lance, Fox Hills, Fort Union, and Wasatch formations as a multi-layer aquifer system. This system was modeled by using the program for simulation of three dimensional ground-water flow developed by Trescott and Larson (1976). This program is routinely used by USGS for simulating multi-layer aquifer systems.

Because of limited data, it was assumed that the formations in the aquifer system have uniform hydraulic properties (Figure 4-5 and Table 4-3), and that the underlying cretaceous shales are impermeable. The horizontal hydraulic conductivity in all formations was specified as 4×10^{-7} ft/sec, the vertical hydraulic conductivity was specified as 2×10^{-10} ft/sec, and the storage coefficient was specified as 2.1×10^{-7} per foot of formation thickness except in outcrop areas, where it was specified as 0.1 per foot. These values are a best estimate of aquifer parameters based on available data; however, since the data are limited, the estimates have been conservatively biased to provide worst-case estimates of project impacts. The aquifer system was simulated numerically using a six layer model so that drawdowns in both the horizontal and vertical directions could be calculated (Figure 4-5).

Pumping from the North Well Field at a rate of 2,040 acre-feet per year for a period of 30 years was calculated to have only a very small probability of causing any significant impacts on any existing water users, or on the flow in any springs or streams (Figure 4-6). The probable water level declines in the Wasatch Formation and upper Fort Union Formation, in which all water wells in the vicinity of the well field are completed, were calculated to be less than five feet after 30 years of pumping. Water level declines in the nearest Lance-

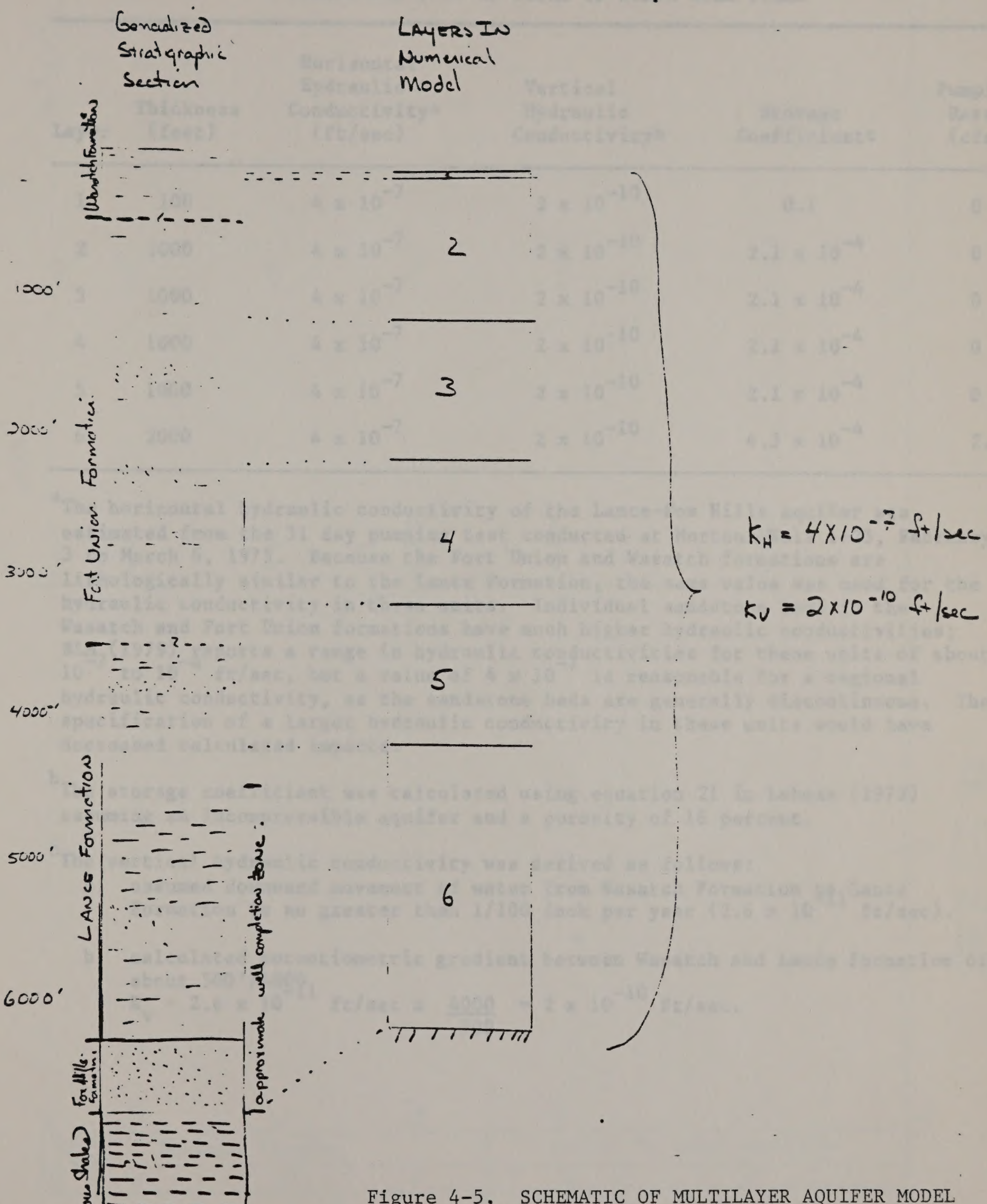


Figure 4-5. SCHEMATIC OF MULTILAYER AQUIFER MODEL FOR THE NORTH WELL FIELD.

TABLE 4-3
PARAMETERS USED IN MODEL OF NORTH WELL FIELD

Layer	Thickness (feet)	Horizontal Hydraulic Conductivity[a] (ft/sec)	Vertical Hydraulic Conductivity[b]	Storage Coefficient[c]	Pumping Rate (cfs)
1	100	4×10^{-7}	2×10^{-10}	0.1	0
2	1000	4×10^{-7}	2×10^{-10}	2.1×10^{-4}	0
3	1000	4×10^{-7}	2×10^{-10}	2.1×10^{-4}	0
4	1000	4×10^{-7}	2×10^{-10}	2.1×10^{-4}	0
5	1000	4×10^{-7}	2×10^{-10}	2.1×10^{-4}	0
6	2000	4×10^{-7}	2×10^{-10}	4.3×10^{-4}	2.82

[a]The horizontal hydraulic conductivity of the Lance-Fox Hills aquifer was estimated from the 31 day pumping test conducted at Mortons Well 1-23, February 3 to March 6, 1975. Because the Fort Union and Wasatch formations are lithologically similar to the Lance Formation, the same value was used for the hydraulic conductivity in these units. Individual sandstone beds in the Wasatch and Fort Union formations have much higher hydraulic conductivities; BLM (1979) reports a range in hydraulic conductivities for these units of about 10^{-7} to 10^{-4} ft/sec, but a value of 4×10^{-7} is reasonable for a regional hydraulic conductivity, as the sandstone beds are generally discontinuous. The specification of a larger hydraulic conductivity in these units would have decreased calculated impacts.

[b]The storage coefficient was calculated using equation 21 in Lohman (1972) assuming an incompressible aquifer and a porosity of 16 percent.

[c]The vertical hydraulic conductivity was derived as follows:

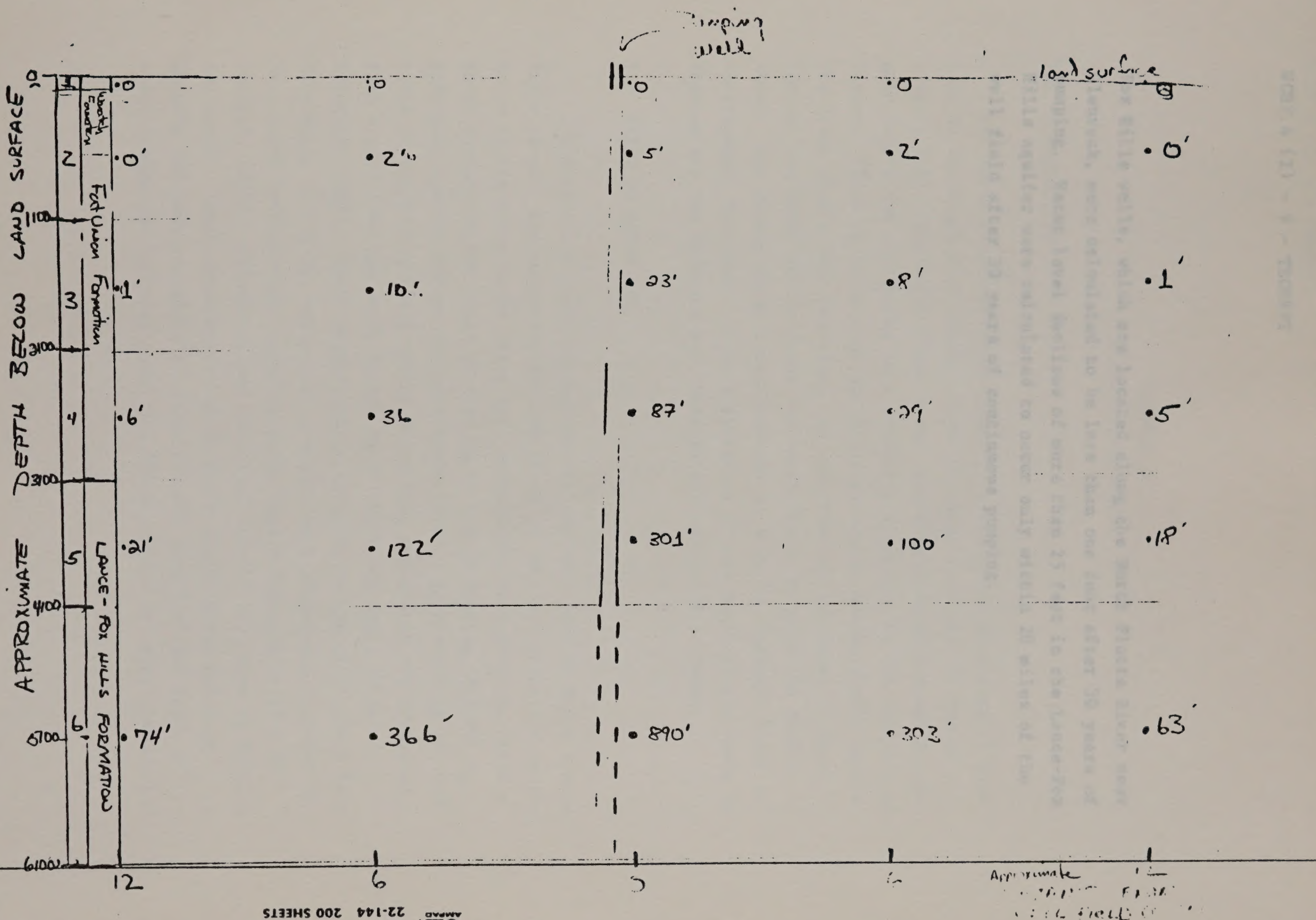
a. assumed downward movement of water from Wasatch Formation to Lance Formation is no greater than 1/100 inch per year (2.6×10^{-11} ft/sec).

b. calculated potentiometric gradient between Wasatch and Lance formation of about 500'/4000.

$$K_v = 2.6 \times 10^{-11} \text{ ft/sec} \times \frac{4000}{500} = 2 \times 10^{-10} \text{ ft/sec.}$$

Figure 4-6. Calculated drawdowns in the Wasatch, Fort Union and Lance-Fox Hills Aquifers

After 30 years of Pumping From the North Well Field



Fox Hills wells, which are located along the North Platte River near Glenrock, were calculated to be less than one foot after 30 years of pumping. Water level declines of more than 25 feet in the Lance-Fox Hills aquifer were calculated to occur only within 20 miles of the well field after 30 years of continuous pumping.

Chapter 5
NORTH PLATTE RIVER

5.A INTRODUCTION

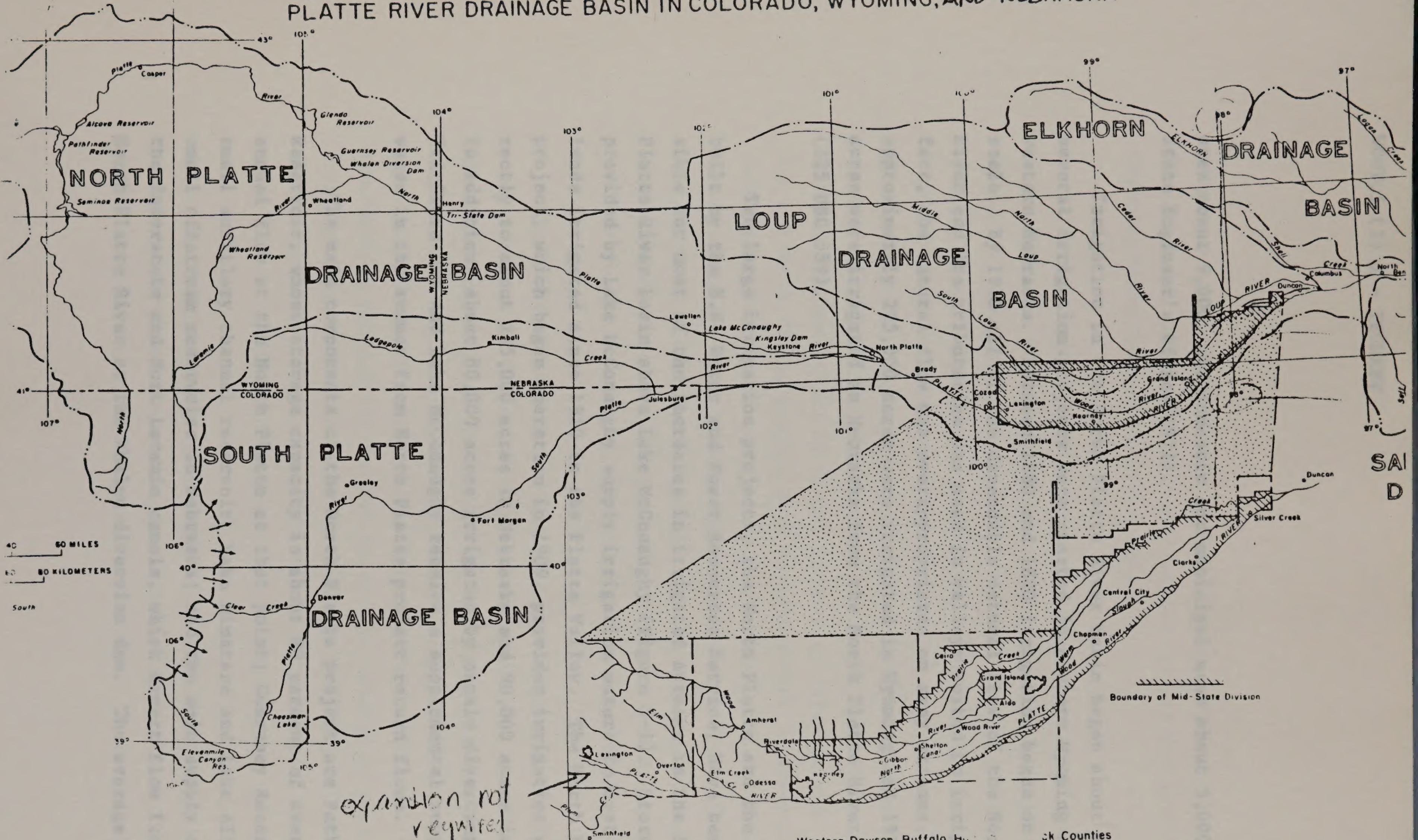
The North Platte River originates in the Rocky Mountains of Colorado in the North Park Valley, about 60 miles northeast of Denver (Figure 5-1). The river flows north, entering Wyoming through Northgate Canyon and continuing in a northerly direction to the vicinity of Casper. There it turns east and flows generally southeasterly across the Great Plains into Nebraska. In west-central Nebraska, at North Platte, the North Platte joins the South Platte to form the Platte River. The Platte River flows eastward to join the Missouri River at Plattsmouth, Nebraska. Major tributaries of the North Platte River in Wyoming are the Medicine Bow, Sweetwater, and Laramie rivers.

5.B EXISTING WATER USE

Irrigation and power production are the main uses of North Platte River water. Approximately 810,000 acres of land are irrigated in the North Platte River basin above Lake McConaughy, excluding the Laramie River basin; 356,000 acres of this total are in Wyoming, 319,000 in Nebraska, and 135,000 in Colorado (WPRS 1957). Approximately 230,000 acres of the Platte River valley below Lake McConaughy are irrigated with waters from the North Platte River (Nebraska Dept. of Water Resources 1980). Total hydroelectric capacity on the river above Lake McConaughy is 181 MW, and annual average power production is about 90 MW. Total hydroelectric capacity below Lake McConaughy is 63.5 MW (Bentall 1975). Industrial and municipal uses of the water in Wyoming are small. Total consumptive use of North Platte River water in Wyoming has been estimated at about 588,000 acre-feet per year, of which irrigation consumes about 574,000 acre-feet per year, industrial

Fig. 5-1

PLATTE RIVER DRAINAGE BASIN IN COLORADO, WYOMING, AND NEBRASKA



uses about 9,000, and domestic and municipal uses about 5,000 (Wyoming State Engineer's Office 1971).

Irrigation in the North Platte River basin began about 1865 when several irrigation projects were started in eastern Wyoming and western Nebraska. Between 1880 and 1890 irrigation began on a large scale. By 1910 all of the dependable natural flow of the North Platte River and its tributaries was used in valleys suited to irrigation; in fact, the natural flow was overappropriated on many streams. In 1910, approximately 225,000 acres were irrigated in Wyoming and 192,000 acres were irrigated in Nebraska from the North Platte River system (325 USC 589).

Two large irrigation projects, the North Platte and the Kendrick, built by the U.S. Water and Power Resources Service, have been responsible for most of the increases in irrigated acreage in the North Platte River basin above Lake McConaughy (Figure 5-1). Storage waters provided by Lake McConaughy supply irrigation waters to most of the lands irrigated since 1910 in the Platte Valley. The North Platte project, which began operation in 1909, provides irrigation water directly to about 235,000 acres in Nebraska and 90,000 acres in Wyoming. In addition, about 80,000 acres irrigated by canals diverting between Tri-State Dam and Lake McConaughy receive a supplemental supply of water in the summer from North Platte project return flows.

The main components of the North Platte project are Pathfinder Reservoir, whose storage capacity is about 80 percent of average annual flow at the North Platte at that point; Guernsey Reservoir, a small auxillary channel reservoir; Lake Minatare and Lake Alice, two small offstream reservoirs in Nebraska; and two main supply canals, the Interstate and Fort Laramie canals, which divert flow from the North Platte River at the Whalen diversion dam. The average annual

diversion to the Fort Laramie and Interstate canals at the Whalen diversion dam during the 1951-1971 period was 762,000 acre-feet (Wyoming State Engineer's Office 1971).

The efficiency by which water could be transferred from Pathfinder Reservoir to the Whalen diversion dam, a river distance of about 400 miles, was greatly improved by the construction of Glendo Reservoir in 1956. North Platte project water can now be moved downstream to Glendo Reservoir during the winter months, and summer releases from Glendo Reservoir can be set equal to the actual demand at Whalen diversion dam, which is only 20 miles downstream from Glendo Reservoir. Prior to the completion of Glendo Reservoir, releases from Pathfinder for the North Platte project were frequently not in synchronization with demand because of the long transport time from Pathfinder to the Whalen diversion dam. Glendo Reservoir can also store 15,000 acre-feet of flood waters for irrigation uses in Wyoming and 25,000 acre-feet of flood water for irrigation in Nebraska. To date, only about half of the water has been contracted for (Hunter 1981).

The Kendrick project was designed to irrigate about 66,000 acres north and west of Casper, Wyoming. Construction of the Kendrick project began in 1933, but irrigation of Kendrick project lands did not begin until 1946, due to lack of water. About 35,000 acres are irrigated with Kendrick waters today (Hunter 1981). The major features of the Kendrick project are Seminoe Reservoir, located 30 miles above Pathfinder Reservoir, which has a capacity of 1,026,400 acre-feet; and Alcova Reservoir, with a capacity of 190,500 acre-feet, located 13 miles below Pathfinder Reservoir.

Lake McConaughy, completed in 1941 on the North Platte River in Nebraska just above the confluence with the South Platte, provides irrigation waters to eight canals in the Platte River Valley above

Kearny, which irrigate 230,000 acres (Nebraska Dept. of Water Resources 1980). An average of about 236,000 acre-feet of water per year was supplied to these eight canals from 1969 to 1979; most was diverted at the Tri-County diversion dam, located just downstream of the confluence of the North and South Platte rivers.

The U.S. Water and Power Resources Service operates six hydroelectric plants on the North Platte River in Wyoming. A generating station is located at each of the major reservoirs in Wyoming: Seminoe, Kortes, Pathfinder (Fremont Canyon Power Station), Alcova, Glendo, and Guernsey; power generation and capacity for these plants are listed in Table 5-1.

Five hydroelectric plants use water diverted from the Platte River system in Nebraska. The Nebraska Public Power District diverts water via the Sutherland Canal from the North Platte River below Lake McConaughy, and from the South Platte River near Korty, for the North Platte hydroelectric power plant south of the city of North Platte. This power plant has a generating capacity of 26 MW. The Central Nebraska Public Power and Irrigation District operates three hydroelectric plants along the Tri-County Supply Canal. The Jeffrey Power Plant and Johnson Power Plants No. 1 and No. 2 have a combined generating capacity of _____ MW. A small power plant on the west edge of Kearny has a generating capacity of 1.5 MW.

The major municipal users of North Platte River water are the cities of Casper and Douglas (Table 5-2). The city of Douglas began using North Platte River water in 1980 to supplement its existing spring water supply system during the summer months. The Douglas supply system is designed to withdraw 2,800 acre-feet per year from the river, although it was designed to be expandable to a capacity of 4,480 acre-feet per year (Carter 1981).

TABLE 5-1

HYDROELECTRIC GENERATING STATION--NORTH PLATTE RIVER

Station Name	Total Capacity (MW)	Average Power Generation 1962-1972 (MW)
Seminoe	32.4	15.4
Kortes	36.0	17.6
Fremont Canyon	48.0	27.4
Alcova	36.0	13.5
Glendo	24.0	9.9
Guernsey	4.8	3.0
North Platte	26.0	-

Sources: Wei (1977); Benthall (1975).

TABLE 5-2

MUNICIPAL WATER USE FROM THE NORTH PLATTE RIVER BELOW PATHFINDER RESERVOIR (acre-feet)

Community	1980 Water Use
Casper	13,800[a]
Evansville	1.6
Mills	476
Wardwell	537
Douglas	560

Source: Brogan 1981 and Carter 1981

[a]This includes diversions from the river as well as net pumpage from the alluvial well field adjacent to the river.

5.C FUTURE WATER USE

The U.S. Fish and Wildlife Service (1978) and Lynott (1981) listed projects that may reasonably be expected to become operational in the near future and that will cause significant depletions in the flow of the North Platte and Platte rivers. These projects and estimated depletions are shown in Figure 5-1, listed in Table 5-3, and discussed below.

1. Laramie River Power Station and Grayrocks Dam and Reservoir

The Laramie River Power Station near Wheatland, Wyoming, is a 1,500-MW coal-fired power plant scheduled to go into operation in 1981. The power plant is estimated to have an annual consumptive use of water, for cooling and reservoir evaporation, of 23,000 acre-feet per year (Banner Associates 1978). Water for the power plant will come from Grayrocks Reservoir, with a total storage capacity of 104,100 acre-feet, which is being constructed on the Laramie River about 10 miles upstream from the mouth. The power plant and reservoir are owned by the Missouri Basin Power Project.

2. The Corn Creek Irrigation Project

The Corn Creek Irrigation project is proposed to irrigate 15,000 acres east and south of the mouth of the Laramie River near Fort Laramie, Wyoming. The potential sources of water for this project are 22,500 acre-feet per year from the Laramie River, pursuant to a contractual agreement with Basin Electric, and 10,000 acre-feet per year from Wyoming's share of Glendo Unit water. The U.S. Fish and Wildlife Service (1978) estimated the average annual consumptive use of water by this project to be 30,000 acre-feet per year; actual consumptive use based on realistic irrigation efficiencies is likely to be about 16,000 acre-feet per year.

TABLE 5-3

ESTIMATED FUTURE CONSUMPTIVE USES--PLATTE RIVER SYSTEM

Project	Average Annual Depletion (in year 2000) (acre-feet)
WyCoalGas	8,000
Laramie River Power Station	23,000
Corn Creek Irrigation Project	30,000
Wildcat Reservoir--Pawnee Power Plant	14,000
Gerald Gentleman Power Plant	5,000
Agricultural Ground-Water Pumping, Nebraska	100,000
Little Blue Transbasin Diversion and Prairie Bend Unit, Nebraska	100,000
TOTAL	280,000

Sources: U.S. FWS (1978); Banner Associates (1981).

3. Wildcat Reservoir and Pawnee Power Plant

The proposed Wildcat Dam and Reservoir are located in the South Platte River basin near Morgan, Colorado. The reservoir will have 60,000 acre-feet of conservation storage and will provide cooling water to two 500-MW generating units (the Pawnee Power Plant) to be located near Brush, Colorado. The first generating unit is now under construction. The U.S. Fish and Wildlife Service estimated annual depletion by this project of 14,000 acre-feet per year.

4. Gerald Gentleman Power Plant

The Gerald Gentleman Power Plant is located adjacent to Lake Sutherland near North Platte, Nebraska. The 1,300-MW power plant is estimated to consume 5,000 acre-feet per year when it begins operation (FWS 1978).

5. Ground-Water Withdrawals for Irrigation in Nebraska

Potential ground-water depletions of flows in the North Platte, South Platte, and Platte rivers within the state of Nebraska as a result of increased water use for irrigation were estimated in the Platte River Level B Study (MRBC 1975a, 1976). The U.S. Fish and Wildlife Service (1978) interpreted these studies to estimate a potential depletion of flow over current levels in the Platte River at Overton of 100,000 acre-feet per year by the year 2000, and 233,000 acre-feet by the year 2020.

6. Little Blue Transbasin Diversion and Prairie Bend Unit

The Little Blue and Prairie Bend Units are irrigation projects proposed for central Nebraska. The Prairie Bend Unit would divert wastes for irrigation of lands between Kearney and Grand Island. The Little Blue Unit would divert water out of the Platte River basin from September to January and in April for irrigation, ground-water recharge, streamflow enhancement, recreation, fish and wildlife and

flood control. Only one of the projects is likely to be built, therefore, only depletions from one of the projects are considered.

5.D WATER ALLOCATION

Water appropriations on the North Platte River in Wyoming are governed by Wyoming water law and by the North Platte Decree of 1945 (325 USC 589) and the 1953 amendments to the decree. Wyoming water law is based on a system of prior appropriation, adopted in 1889 and now supervised by the Wyoming State Engineer and the Wyoming Board of Control. Priority is based upon the relative date on which applications for permits to use water and construct works were accepted in the State Engineer's Office. Water allocation in Nebraska is also based on a system of prior appropriation, established by the Nebraska Legislature in 1895 and supervised by the Department of Water Resources.

The independent allocation of water in the North Platte River by both Wyoming and Nebraska according to their respective prior appropriation systems led to a conflict between the states when natural flows were depleted in the early 1900s. The completion of Pathfinder Reservoir in 1909, which provided large quantities of storage water for irrigation, prolonged resolution of the conflict for several decades. Water shortages during the dry years of the early 1930s, and the granting of a water right by Wyoming for the Kendrick project, which began construction in 1933, brought the conflict to a head. In 1934 Nebraska brought suit against Wyoming over the administration of waters in the system, and later sued the state of Colorado as well (239 USC 523). Nebraska alleged that Wyoming and Colorado, by diverting water from the river for irrigation purposes, were violating the rule of priority of appropriation in force in the three states, and depriving Nebraska of water to which it was equitably entitled.

(Hendrickson [1975] provides an excellent review of the interstate conflict on the North Platte River.)

After a lengthy legal study, the U.S. Supreme Court handed down a decision on October 8, 1945, establishing a system of allocation for waters that originate above Tri-State Dam, just downstream of the Nebraska-Wyoming state line. Major features of the decree that affected Wyoming, Colorado, and Nebraska were the following:

- Limits on irrigated acreage, storage, and water exports in Colorado
- An upper limit of 168,000 irrigated acres in Wyoming, on the main stem above Guernsey Reservoir and on tributaries entering the North Platte above the Pathfinder Dam exclusion of the Kendrick project
- A limit of 18,000 acre-feet for storage in Wyoming above Pathfinder Reservoir in any water year
- Priority among the reservoirs in Wyoming: Pathfinder, Guernsey, Seminoe, and Alcova
- Priority of French Canal and State Line Canal (which divert water from the North Platte above Tri-State Dam, primarily for irrigation in Nebraska) over Pathfinder, Guernsey, Seminoe, and Alcova
- Allocation of natural flow (all flow in the river except storage water in transit) between Guernsey Dam and Tri-State Dam from May 1 to September 30 as follows: 25 percent to Wyoming and 75 percent to Nebraska

- A formula for calculating reservoir evaporation and river conveyance losses

The decree was amended on January 11, 1953, to permit Colorado to expand its irrigation acreage and to permit Glendo Reservoir to store up to 100,000 acre-feet, with not more than 40,000 acre-feet (in addition to evaporation losses) withheld from the river in any one year. Wyoming lands were given the right to use 15,000 acre-feet per year from Glendo Reservoir, and Nebraska lands were given the right to use 25,000 acre-feet per year.

Allocation of water below Tri-State Dam was excluded from the decree because the court found that irrigation demands could be met from local supplies and return flows (325 CFR 587, 654). Limitation on water use in Wyoming from tributaries between Pathfinder Reservoir and Whalen diversion dam were excluded from the decree because the court "found no evidence of any threat to the water supply from this source" (325 USC 625). The court stated further, "If such threat appears and it promises to disturb the delicate balance of the river, application may be made at the foot of the decree for an appropriate restriction" (325 USC 625).

The decree of 1945, with the 1953 amendments, has been used since its issuance to allocate waters of the North Platte River among the states of Colorado, Nebraska, and Wyoming, although disagreements remain between Wyoming and Nebraska over allocation.

5.E HYDROLOGIC REGIME

Stream flows on the North Platte River are regulated by the seven federal reservoirs in Wyoming, Lake McConaughy in Nebraska, and extensive diversions for irrigation, power production, and industrial uses

in the basin. Natural flow conditions have not prevailed in the North Platte River system since 1865, when the first irrigation diversions were constructed. Flood flows on the main stem were unregulated until Pathfinder Reservoir was completed in 1909. The completion of Seminoe Reservoir in 1939 and Lake McConaughy in 1941 brought the entire river system under the control of man. Glendo Reservoir, completed in 1956, allowed for even finer management, and today the hydrologic regime of the river is almost entirely controlled by man.

The most significant changes in the flow regime of the river occurred during the period from 1909, when Pathfinder Reservoir was completed, to 1956, when Glendo Reservoir was completed. Total consumptive use of water in the system changed markedly, as many new acres were irrigated with waters from four large reservoirs constructed during this time. Total consumptive use has not changed significantly since the late 1950s. A comparison of flow regimes prior to 1909 with those after 1956 is not straightforward because of the paucity of flow records prior to 1909, the short period of record prior to 1913, and climatic differences between the periods before 1913 and after 1956.

Flow regulation for irrigation and power production has had a dramatic effect on the flow regime of the river. Annual flows at the downstream stations in Nebraska today are only about 25 percent of flows prior to completion of Pathfinder Reservoir; the average annual flow at North Platte, Nebraska, was about 2,000,000 acre-feet prior to 1910, and the annual average flow today is about 450,000 acre-feet. The Wyoming State Engineer (1971) estimated that the annual average flow of the river at the state line has declined from 1,743,000 acre-feet to 980,000 acre-feet, a decrease of 44 percent. Recorded annual flows near Glenrock, Wyoming, at the Nebraska-Wyoming border, and at North Platte, Nebraska, are shown in Figures 5-2 and 5-3.

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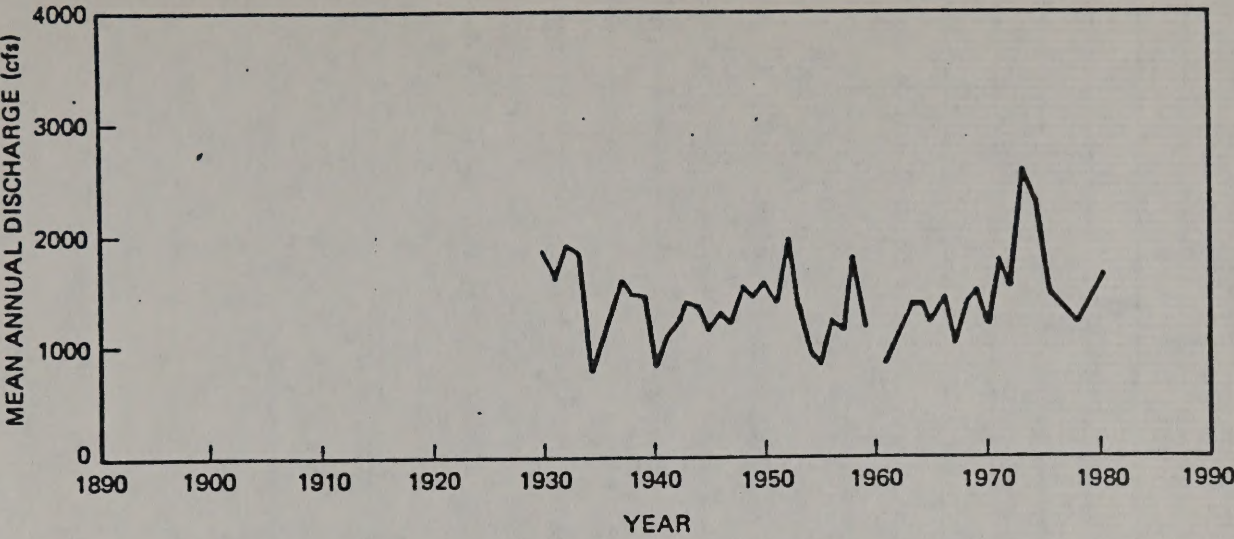


FIGURE 5-2a
MEAN ANNUAL DISCHARGE OF NORTH PLATTE RIVER
NEAR DOUGLAS (1930-1959) AND GLENROCK (1961-1980).

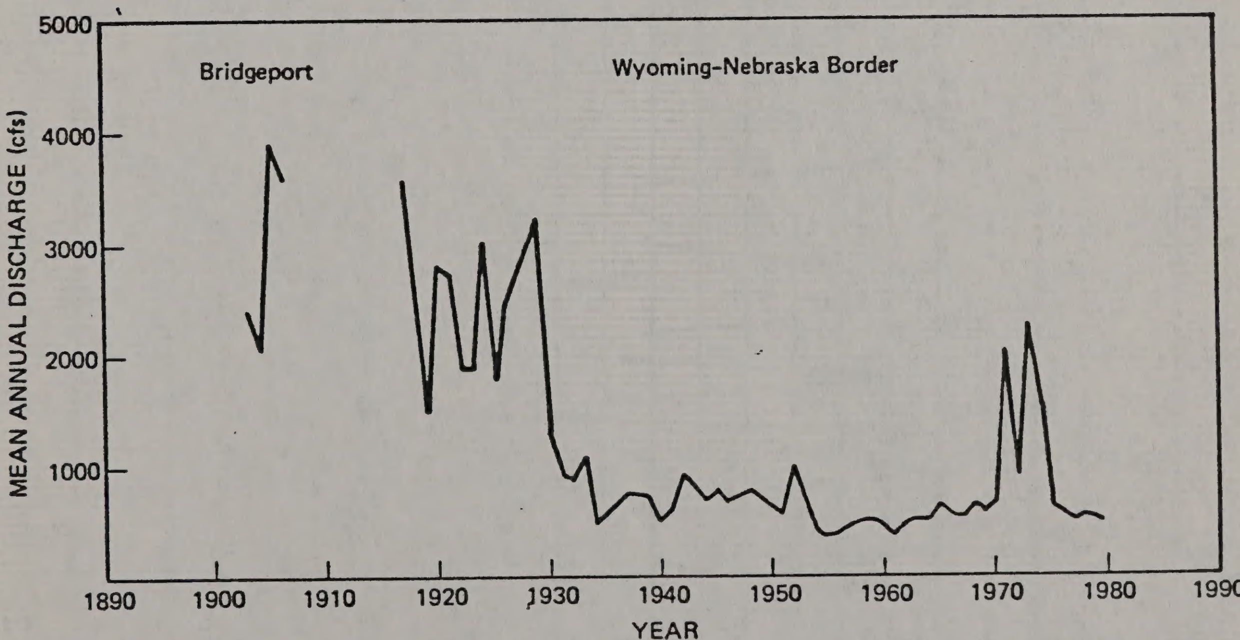


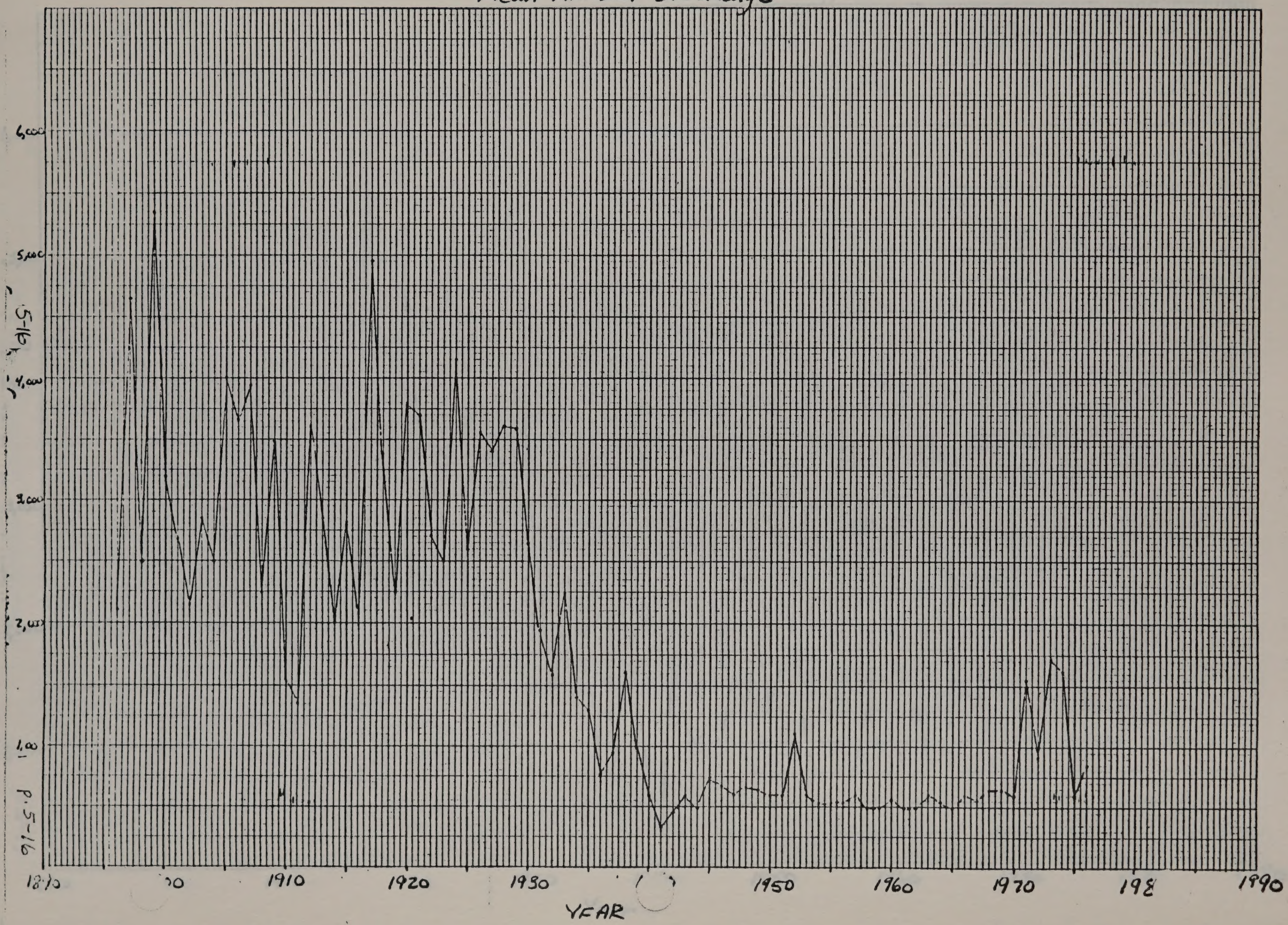
FIGURE 5-2b
MEAN ANNUAL DISCHARGE OF NORTH PLATTE RIVER
AT BRIDGEPORT (1903-1929) AND WYOMING-NEBRASKA
BORDER (1930-1979)

46 1320

3-23-81

Figure 5-2c

North Platte River at North Platte
Mean Annual Discharge



3-23-81

Figure 5-2(d)

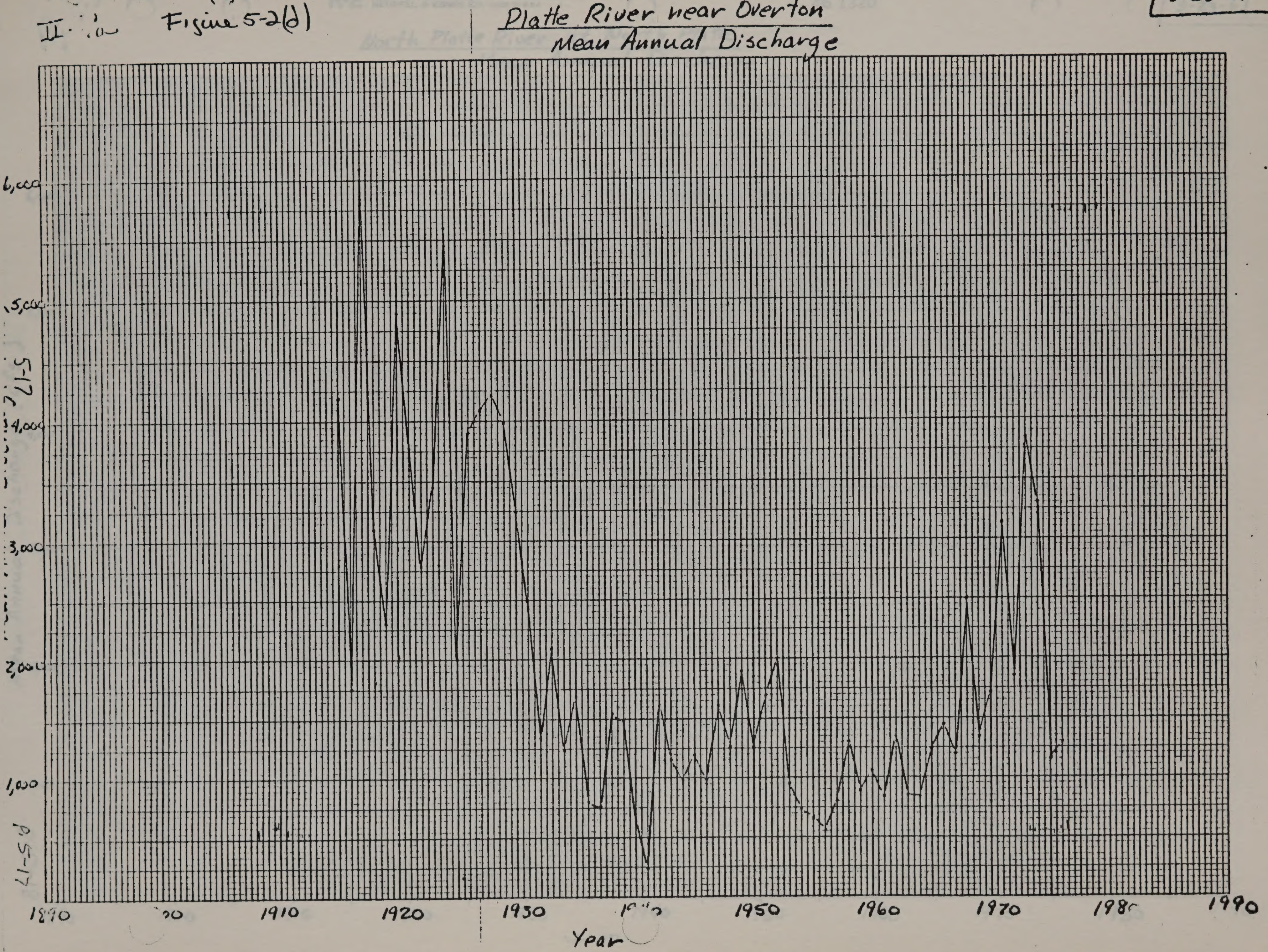


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Fig. 5-3A

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North Platte River at North Platte
Mean Annual Discharge

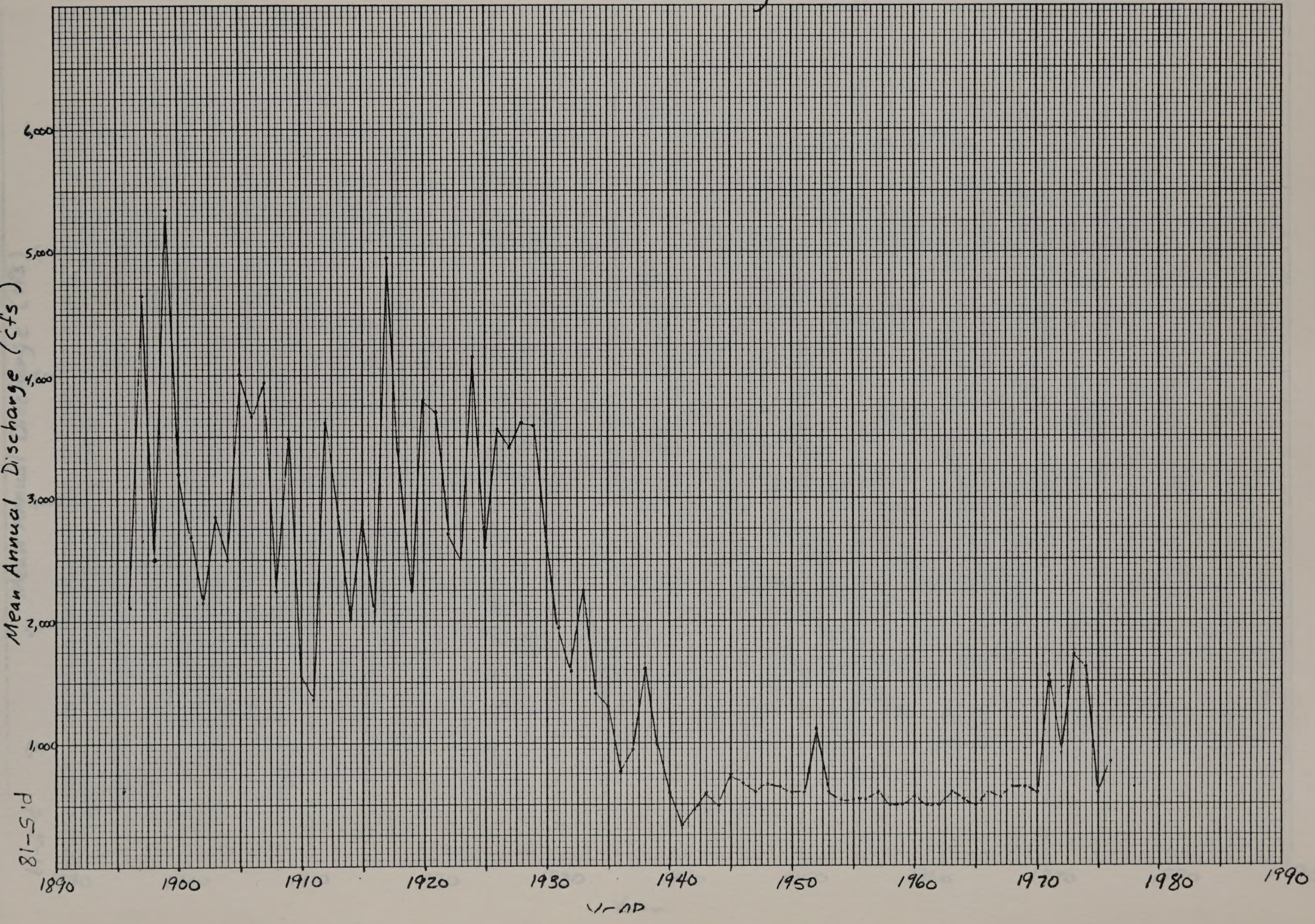

Fig 5.3b

K+E 10 X 10 TO ½ INCH 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A.

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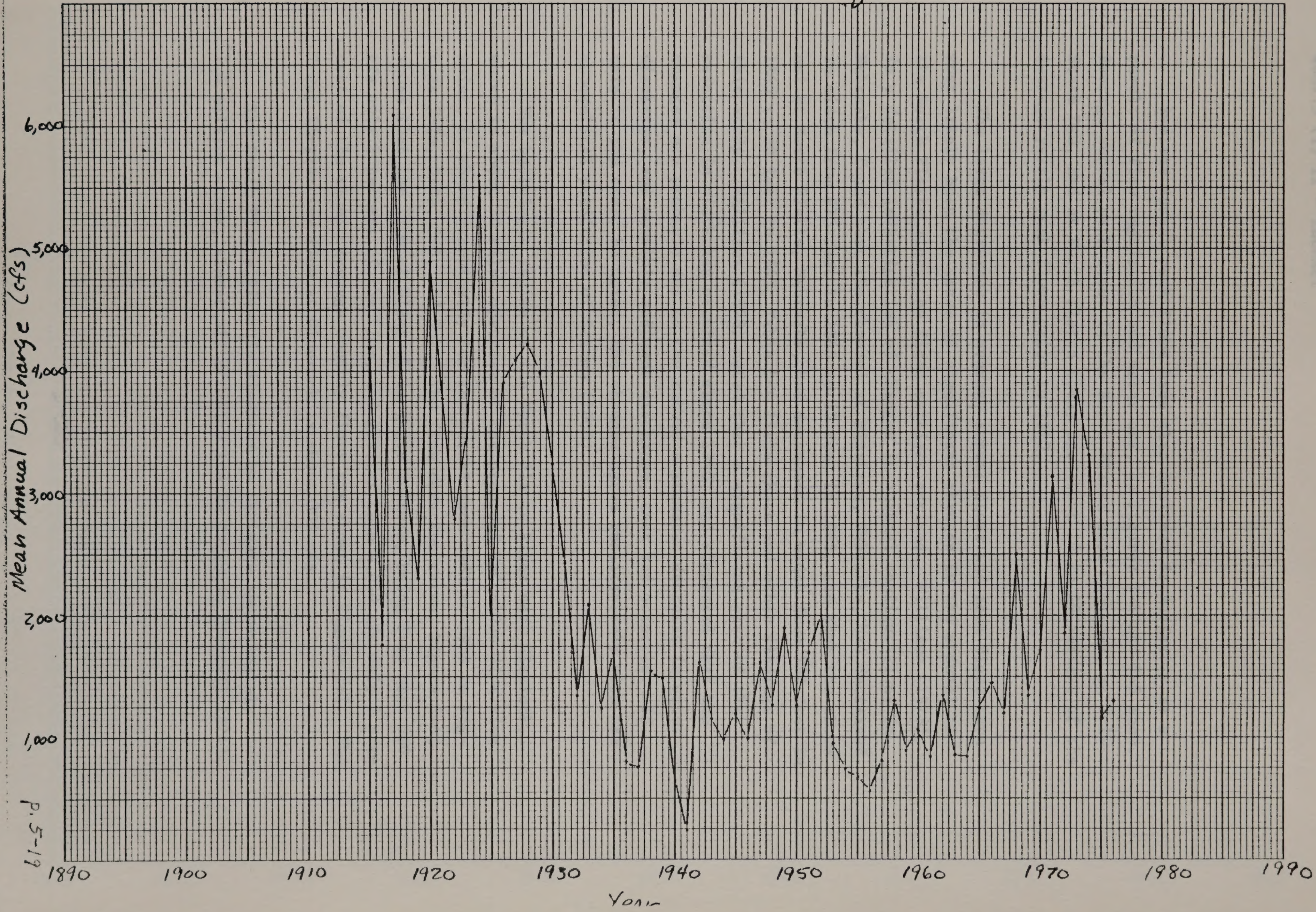
Platte River near Overton
Mean Annual Discharge



p. 5-19

Average annual peak flows have also declined dramatically as a result of flow regulation and water use, as Figures 5-4 and 5-5 show. Average annual peak flows in the North Platte near Glenrock, at Tri-State Dam, and at North Platte today are about 10 to 40 percent of the average yearly peak flows prior to 1910.

The large decreases in average annual flows and peak flows have most likely been the cause of significant changes in the channel of the North Platte since the first settlers arrived. Williams (1978), in a detailed investigation of changes in channel configurations in Nebraska, found that the channel at Minatare, Nebraska, had decreased in width from 975 feet in 1865 to 55 feet in 1965, and that the channel at North Platte, Nebraska, had decreased in width from 790 feet in 1865 to 90 feet in 1965; Table 5-4 lists these and other findings of this study. Williams (1978) noted that a significant part of the reduction in width has occurred since 1940, and suggested that the changes are probably due to the rather systematic decrease in water discharge, and possibly sediment discharge, that has occurred. If this is the case, he noted, the changes agree qualitatively with the theoretical prediction of Schumm (1969).

The hydrologic regime of the North Platte River near Glenrock, which is about 20 miles upstream of the proposed WyCoalGas diversion point, is shown graphically for the period from 1962 to 1979 in Figures 5-2a, 5-4a, 5-6, and 5-7. The flow duration curve, Figure 5-6, shows that the flow at Glenrock is quite uniform, being less than 500 cfs only 1 percent of the time, and greater than 4,000 cfs only 1 percent of the time. Average monthly flows are shown in Figure 5-7. The 7-day 25-year low flow at Glenrock is about 300 cfs.

The South Platte River is diverted to irrigate approximately 1.4 million acres, almost all of which are in Colorado (Bentall 1974).

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North Platte River near Glenrock
Peak Discharge

Fig. 5-4a

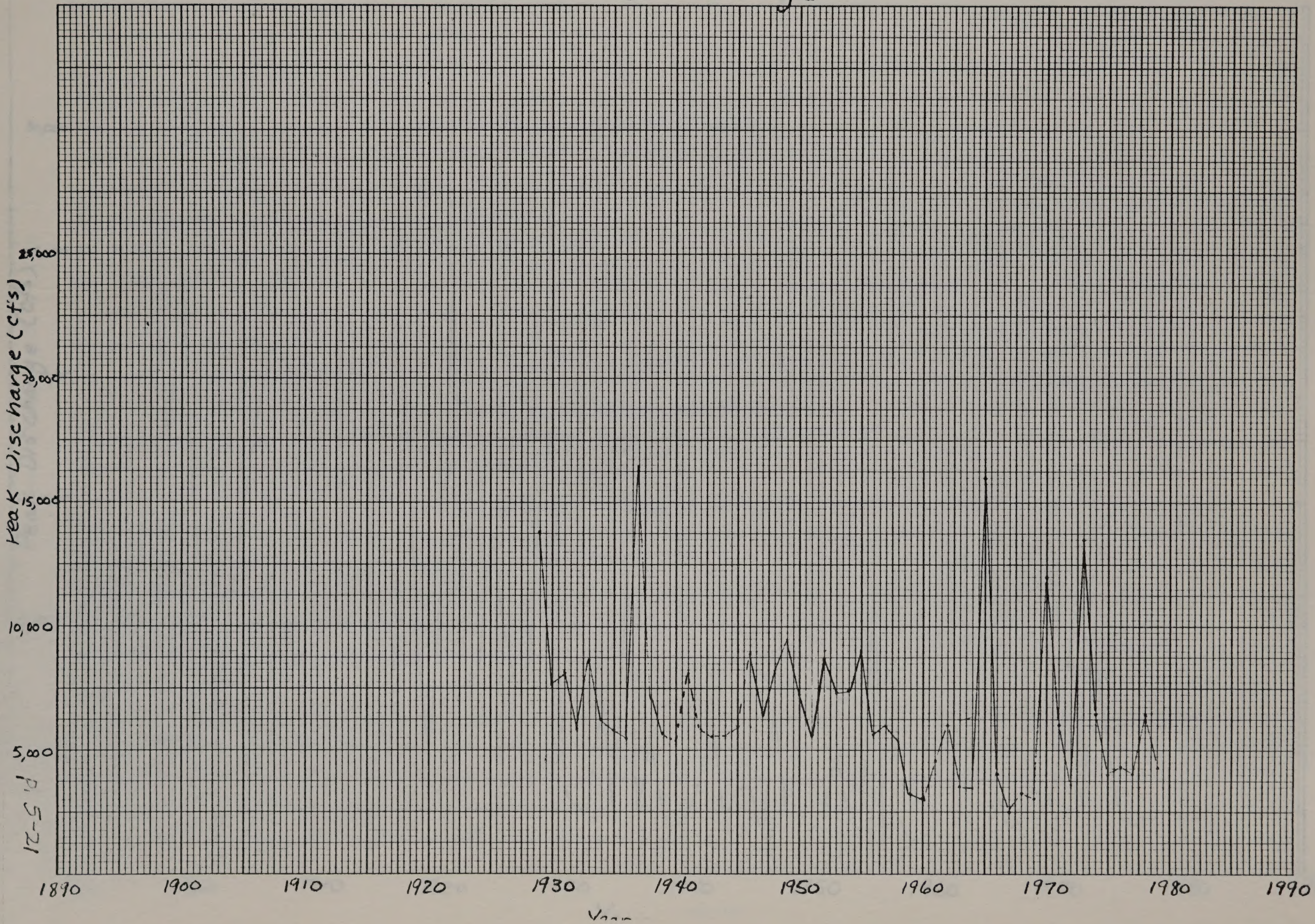

Fig 5-46

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3-24-81

North Platte River at Bridgeport (1897-1928) and Wyo-Nebr State Line (1929-1978)

Peak Discharge

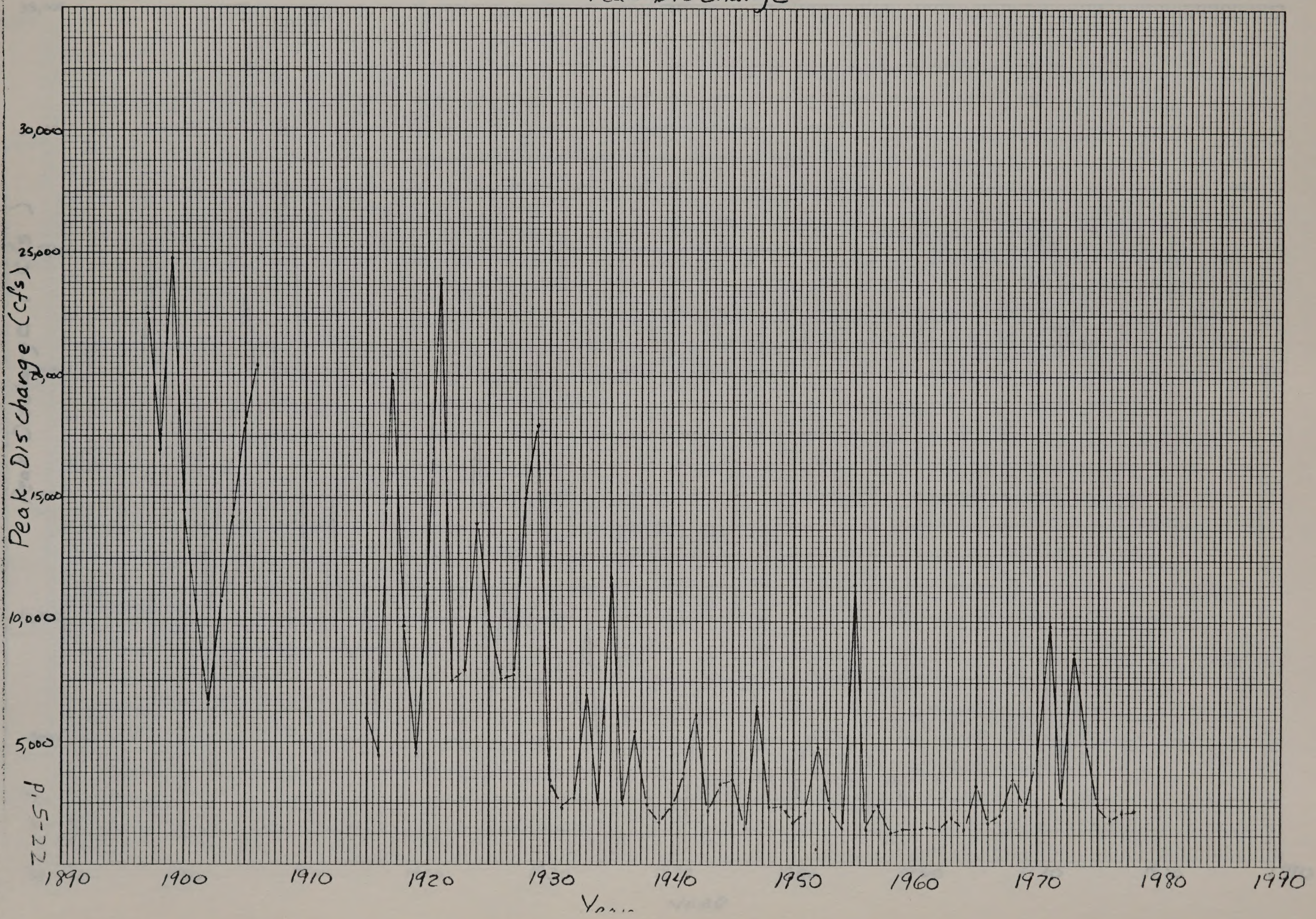

Fig. 5-4c

K•E 10 X 10 TO ½ INCH 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A. 46 1320

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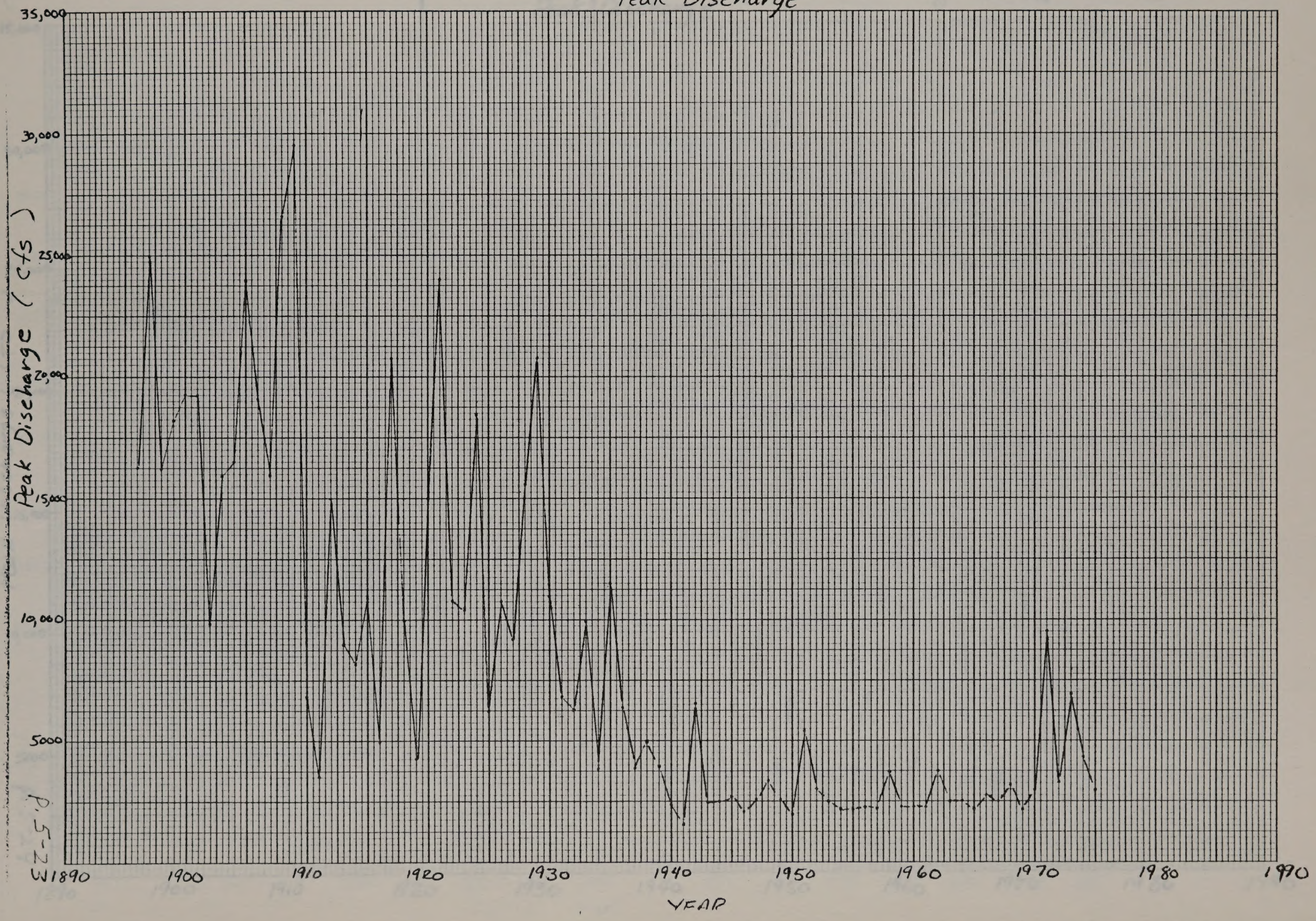
North Platte River at North Platte

Peak Discharge



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5-4d

K+E 10 X 10 TO ½ INCH 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A. 46 1320

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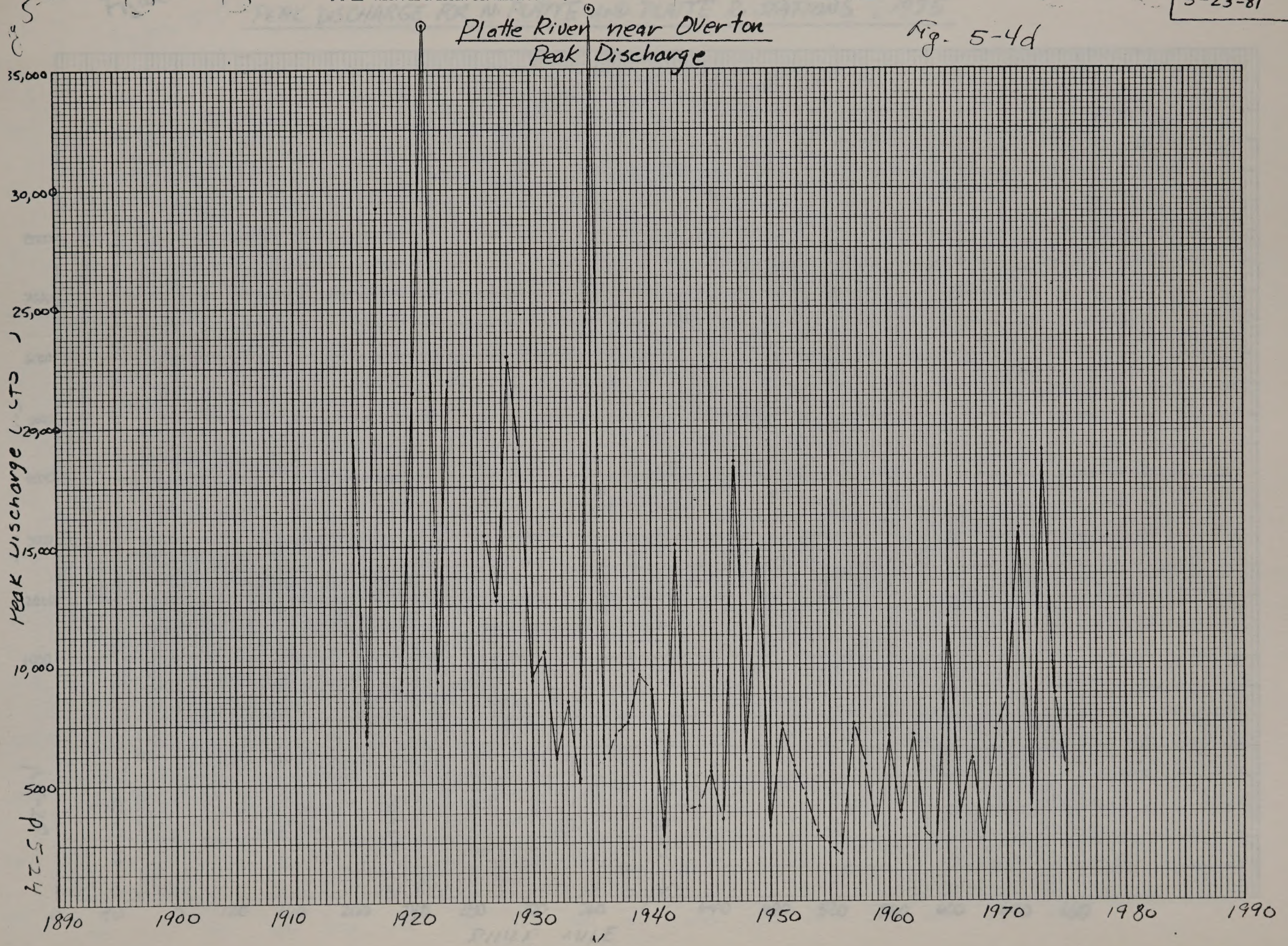
Fig. 5-4d



p. 5-24

K+E 10 X 10 TO ½ INCH 7 X 10 INCHES KEUFFEL & ESSER CO. MADE IN U.S.A. 46 1320

Figure 5-5a

PEAK DISCHARGE FOR N. PLATTE AND PLATTE R. STATIONS, 1975

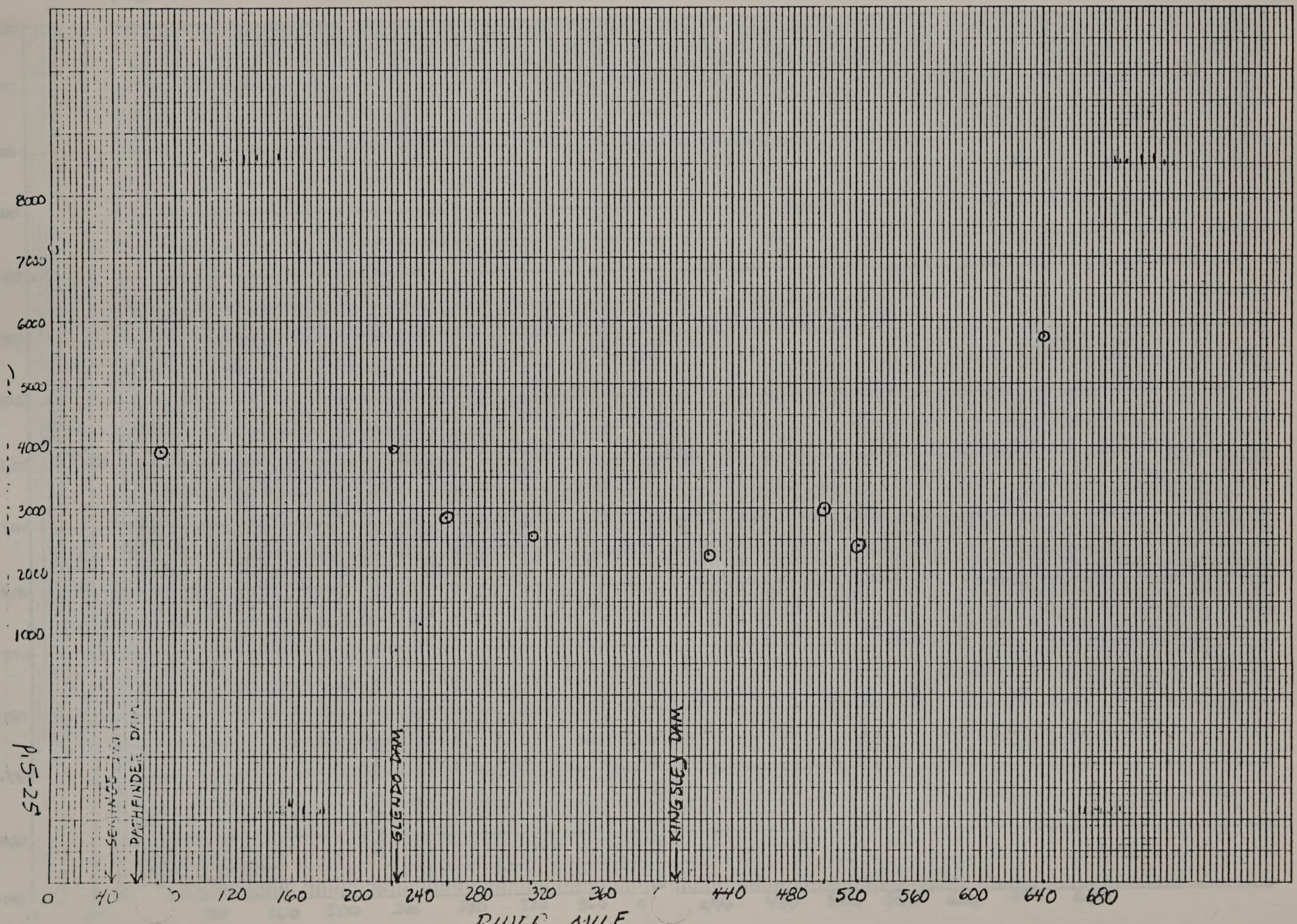


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Figure 5-5b

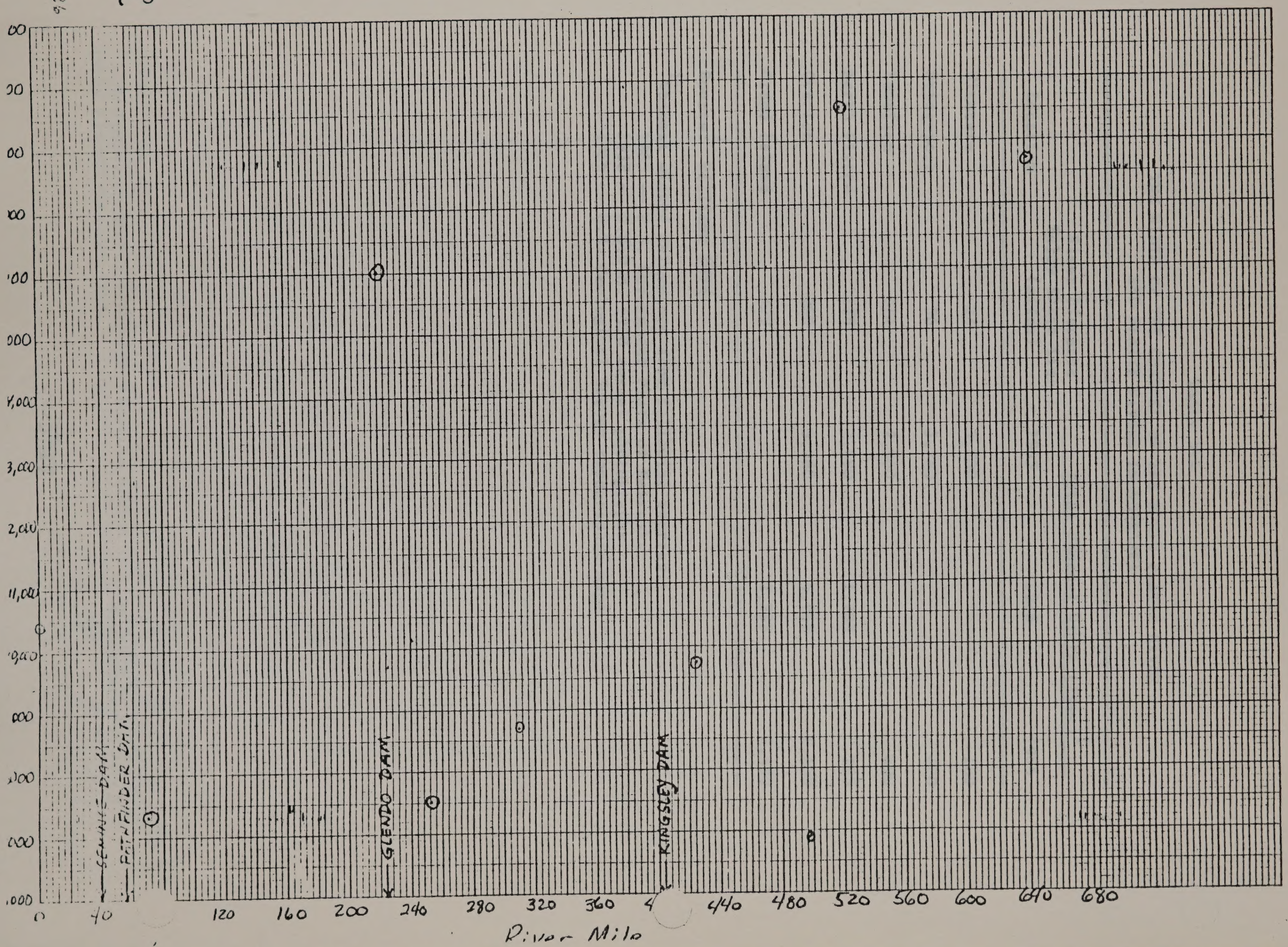
K+E 10 X 10 TO ½ INCH 7 X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.
46 1320
Peak Discharge for N. Platte + Platte R. Stations, 1973
SEMINOE DAM
PATHFINDER DAM
GLENDO DAM
KINGSLEY DAM
14,000
13,000
12,000
11,000
0
40
120
160
200
240
280
320
360
440
480
520
560
600
640
680
River Mile

TABLE 5-4

THE WIDTH OF THE CHANNEL OF THE NORTH PLATTE RIVER AND PLATTE RIVERS IN NEBRASKA

Location	River Distance Below State Line (miles)	Total Channel Width (feet)[1]		
		1865	1938	1965
Minatare	33	3,200		180
Bridgeport	56	3,740		400
Lewellen	114	2,900		490
North Platte	188	2,590	1,705	295
Overton	260	5,280	4,985	1,100
Grand Island	329		2,395	2,490

Source: Williams 1978.

[1] Channel widths determined from following sources:
1865 -- U.S. Government Plats of Nebraska
1938 -- U.S.D.A. 1938 aerial photographs
1965 -- U.S. Geological Survey topographic maps

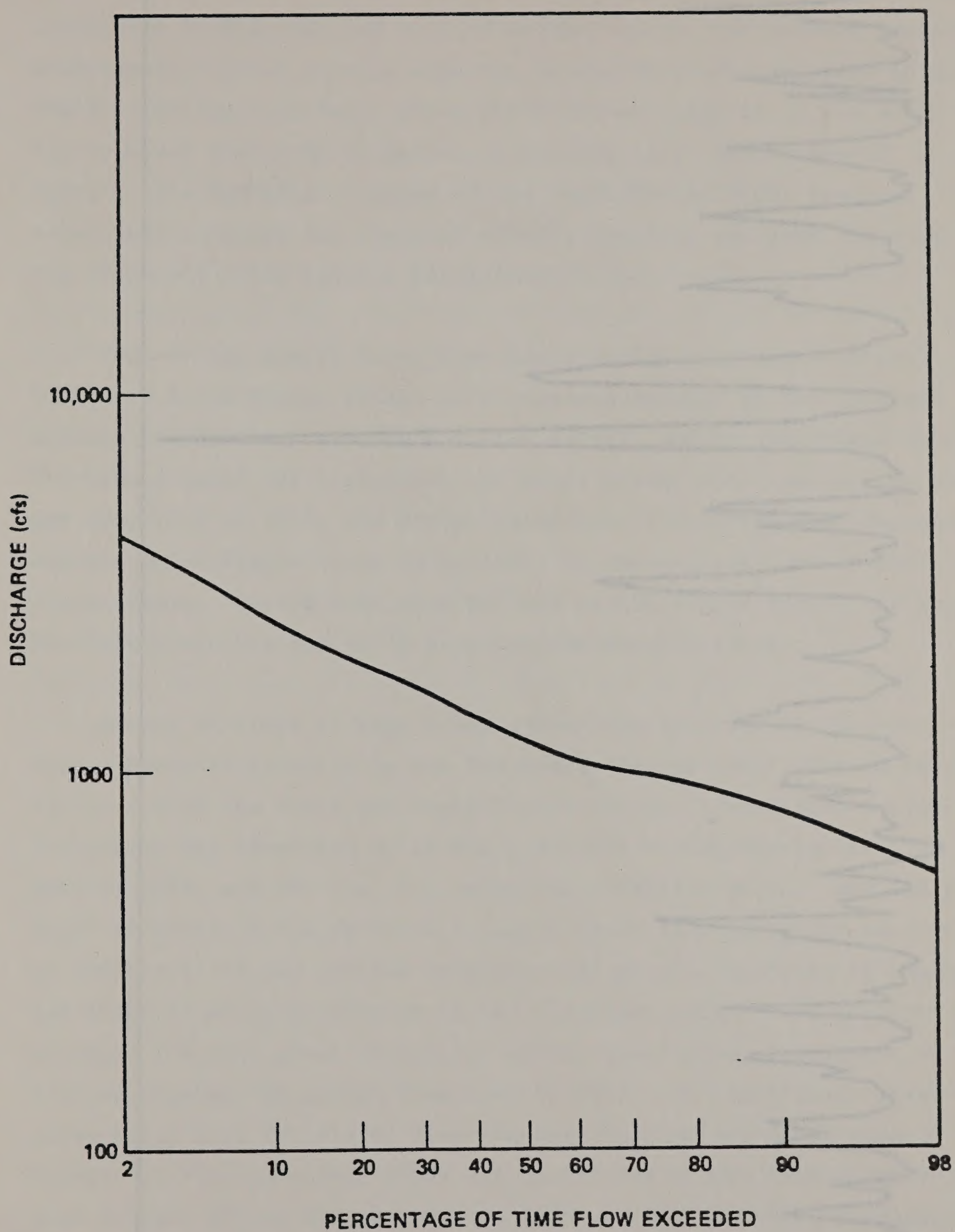

Figure 5-6.
FLOW DURATION CURVE FOR NORTH PLATTE RIVER NEAR GLENROCK (1961-1980)

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5-29

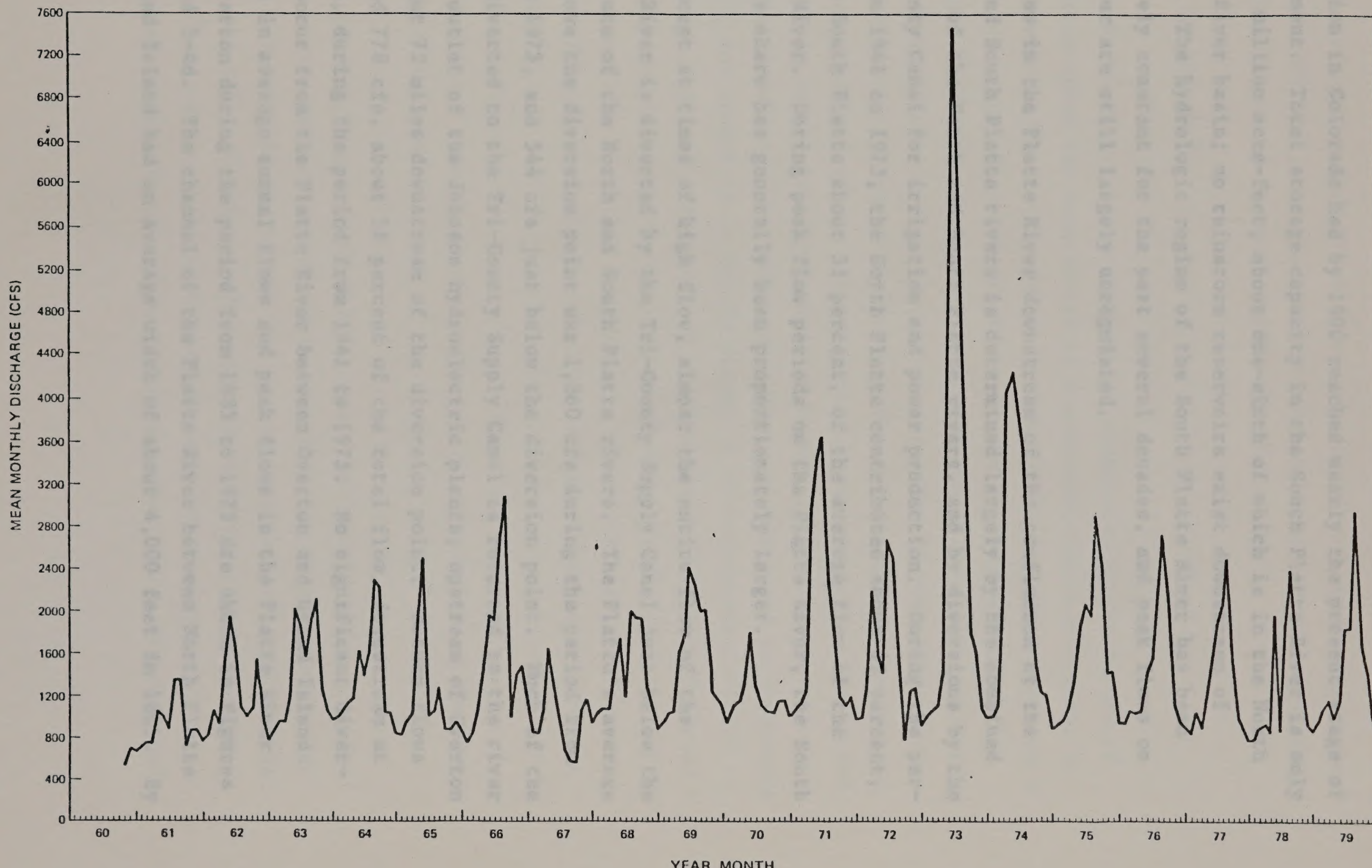


Figure ~~2.3.2-5~~ 5-7
AVERAGE MONTHLY FLOWS
NORTH PLATTE RIVER NEAR GLENROCK, WYO (1961-1980)

GRAPHICS
geoherial 7/29/81

Irrigation in Colorado had by 1900 reached nearly the present stage of development. Total storage capacity in the South Platte River is only about 1 million acre-feet, about one-sixth of which is in the North Platte River basin; no rainstorm reservoirs exist downstream of Denver. The hydrologic regime of the South Platte River has been relatively constant for the past several decades, and peak flows on the river are still largely unregulated.

Flow in the Platte River downstream of the confluence of the North and South Platte rivers is determined largely by the combined inflows of the North and South Platte rivers, and by diversions by the Tri-County Canal for irrigation and power production. During the period from 1941 to 1973, the North Platte contributed about 69 percent, and the South Platte about 31 percent, of the average flow of the Platte River. During peak flow periods on the Platte River, the South Platte's share has generally been proportionately larger.

Except at times of high flow, almost the entire flow of the Platte River is diverted by the Tri-County Supply Canal just below the confluence of the North and South Platte rivers. The Platte's average flow above the diversion point was 1,860 cfs during the period from 1941 to 1973, and 544 cfs just below the diversion point. Much of the water diverted to the Tri-County Supply Canal is returned to the river at the outlet of the Johnson hydroelectric plants, upstream of Overton and about 72 miles downstream of the diversion point. Return flows averaged 778 cfs, about 58 percent of the total flow, downstream at Overton, during the period from 1941 to 1973. No significant diversions occur from the Platte River between Overton and Grand Island. Changes in average annual flows and peak flows in the Platte River near Overton during the period from 1885 to 1975 are shown in Figures 5-2d and 5-4d. The channel of the Platte River between North Platte and Grand Island had an average width of about 4,000 feet in 1865. By

1965 the average channel width between North Platte and Lexington was only about 300 feet, and the channel width between Lexington and Grand Island had decreased to about 2,000 feet (Table 5-4).

5.F RIVER OPERATION

The North Platte River in Wyoming is operated by the Bureau of Reclamation under the supervision of the Wyoming Board of Control in Mills, Wyoming. The river system is generally operated by two sets of rules based on the North Platte River Decree of 1945, as amended in 1953. The first set of rules is reservoir operation criteria based on the physical limits of the reservoirs, the needs of downstream areas, consideration of Bureau of Reclamation Western Division hydroelectric operations, and experience gained through past operation. The second set of rules is the legally-derived ownership accounting procedures to determine distribution of the natural flow, restrictions on irrigation delivery, and amount of ownership stored in the reservoirs. Daily records are kept, by the Bureau of Reclamation and the Wyoming Board of Control, of reservoir levels, river flows, natural flow, and diversions, as well as ownership accounting. The North Platte and Platte rivers in Nebraska are operated by the Nebraska Department of Water Resources.

The general pattern of operation for the reservoirs on the North Platte System is as follows:

- <u>Seminoe Reservoir</u> (1,016,746 acre-feet active storage). The usual practice is to retain as much water in storage as possible during the summer and to evacuate the reservoir during the fall and winter. This procedure serves these purposes: (1) to ensure maximum reservoir capacity to control spring and summer runoff, (2) to generate power during the fall and

winter, and (3) to retain the reservoir at its fullest storage for fishing and recreation during summer months.

- Pathfinder Reservoir (1,015,888 acre-feet of active storage). The usual practice is to lower Pathfinder Reservoir to a minimum by the end of September and then to increase storage capacity during the fall and winter until approximately 100,000 acre-feet of storage capacity is available for spring runoff. Releases from Pathfinder Reservoir are used to maximize power generation and to meet downstream water demands in coordination with Glendo Reservoir releases.

- Alcova Reservoir (188,783 acre-feet active storage). Alcova Reservoir is kept nearly full during the irrigation season, as the water level in the reservoir must be in the top 10 feet to make deliveries to the Casper Canal for the Kendrick project. About 70,000 acre-feet per year are diverted for irrigation on Kendrick project lands. Gray Reef Dam, below Alcova, serves only to reregulate releases from upstream facilities.

- Glendo Reservoir (506,425 acre-feet active storage). The operation of Glendo Reservoir usually involves the transfer of about half of the storage water ownership from Pathfinder Reservoir (North Platte project ownership) to Glendo Reservoir during the fall and winter. Releases from Glendo Reservoir during the irrigation season generate power and meet downstream water demands. At the end of the irrigation season, the reservoir content is usually at minimum storage. Generally, there are no releases downstream during October to February, except seepage. Release starts in March to refill Guernsey to the power head prior to release to Lake Alice and Lake Minatare.

- Guernsey Reservoir (45,228 acre-feet of active storage). Guernsey Reservoir operations are basically for the reregulation of releases made from upstream reservoirs to meet irrigation requirements within the North Platte project area. Periodically since 1936 water in the reservoir has been evacuated rapidly during July and early August to flush accumulations of sediment into the irrigation distribution system. This is believed to stabilize canal banks and to reduce canal and lateral seepage losses. Nine miles below Guernsey Reservoir is the Whalen diversion dam, where about 762,000 acre-feet per year is diverted into the Fort Laramie and Interstate canals for the North Platte project.

- Lake McConaughy (2,000,000 acre-feet of storage). Lake McConaughy, unlike the reservoirs in Wyoming, is operated not by the Bureau of Reclamation but by the Central Nebraska Public Power and Irrigation District. The normal operation of Lake McConaughy results in a minimum reservoir level at the conclusion of the irrigation season. Releases are usually curtailed in early fall so that only sufficient water to meet downstream power generation commitments is released. Downstream of Lake McConaughy at Keystone Dam, an average of about 725,000 acre-feet per year is diverted to the Sutherland Canal. This water is stored in Sutherland and Maloney reservoirs before being used to generate power at the North Platte plant of the Nebraska Public Power District. The water is returned to the South Platte River just west of the confluence with the North Platte River. Just downstream from the confluence, the TriCounty dam diverts an average of about 900,000 acre-feet for irrigation and power production in the Platte River valley.

An operation model of the North Platte River system has been developed by Tseng Chang Wei and Mike Akerbergs of the Wyoming Water Resources Research Institute (Wei 1977; Akerbergs 1980, 1981). This model, which simulates the actual operation of the river system, is essentially a set of algorithms that mimic the rules used in operating the river. The model has been shown to simulate quite well the actual river operations from 1968 to 1980.

5.G WATER AVAILABILITY

In most years, the flow of the North Platte River in Wyoming is insufficient to meet both the direct diversion rights above Tri-State Dam and the storage rights of the reservoirs on the river. Occasionally, spring runoff is sufficient to fill all of the reservoirs, and water beyond that needed to fulfill all requirements is available in the river. A large spill occurred in the North Platte River in 1973, a very wet year; inflow to Seminoe Reservoir that year was 350 percent of normal.

The North Platte operation model has been used to simulate the North Platte River system during the period 1928 to 1980, to determine what the historic availability of water would have been to the 1974 direct diversion right for Panhandle Pipeline No. 1 if the current water uses and river operations procedures had been in effect during the entire period. The operation model predicted that flows in the river were greater than that needed to meet all rights senior to the 1974 direct diversion in 30 of the 53 years.

5.H WATER QUALITY

A considerable amount of water quality data is available on the North Platte River both upstream and downstream of proposed project

activities. The USGS has collected extensive water quality information from gaging stations near Glenrock (1961-present) and Orin (1966-present). Water quality and in some cases suspended sediment measurements have also been made at a number of other locations, listed in Table 5-5. The USGS station at Orin provides a complete characterization of North Platte River quality (Table 5-6); the data from Glenrock are limited to general water quality parameters, common ions, and nutrients. A summary of the water quality at these stations, in terms of general constituents and common ions, is given in Table 5-7. Based on available data, it appears that Orin and Glenrock water qualities are very similar. A synoptic water quality survey performed during 1976 and summarized in Table 5-8 shows a close correspondence between Orin and Glenrock.

North Platte River water can be characterized as a predominantly calcium-sulfate type water with sodium and biocarbonate occasionally being the predominant cation and anion, respectively. Summaries of trace element content and trace organic and pesticide content at Orin are shown in Tables 5-9 and 5-10, respectively. A comparison of the dissolved component of the trace element contents shows that the suggested maximum contaminant level for selenium only was exceeded. No trace organics or pesticides were detected in these water samples, although chlordane, DDD, DDE, DDT, endosulfan, and PCB were detected in bottom materials.

The average annual salinity load carried by the North Platte River at Glenrock for the water years 1961 through 1980 is tabulated in Table 5-11, and average monthly salinity loads are tabulated in Table 5-12.

TABLE 5-5

LOCATION OF STATIONS AT WHICH WATER QUALITY MEASUREMENTS HAVE BEEN MADE

Description	Location	Period of Record	Number of Samples Minimum	Number of Samples Maximum
At Orin	Lat 42°39'02" Long 105°9'46"	1966-present	1	225
At top of Glendo Reservoir	Lat 42°41'2" Long 105°9'50"	1974-75	2	12
South of Douglas	Lat 42°44'25" Long 105°23'50"	1973-78	1	25
Near Douglas Intake	Lat 42°45'45" Long 105°23'42"	1967-72	13	93
Near Glenrock	Lat 42°50'10" Long 105°45'30"	1960-present	1	361
At Dry Creek	Same as above	1976	1	1
Above PPC 33-75-12	Lat 42°50'25" Long 105°48'7"	1976	1	1
Above Dave Johnston P.P.	Lat 42°50'28" Long 105°48'06"	1974-1975	1	2
At Dry Creek near Glenrock	Lat 42°50'30" Long 105°48'6"	1976	1	5
At Orpha	Lat 42°51'8" Long 105°29'27"	1974-1975	1	2

Source: EPA 1981.

TABLE 5-6

WATER QUALITY PARAMETERS MEASURED AT THE ORIN USGS GAGING STATION DURING THE 1979 WATER YEAR

PARAMETER

General Constituent
- Flow
- Water temperature
- pH
- Specific conductance
- Dissolved solids (residue at 105°C)
- Dissolved Solids (sum)
- Hardness
- Noncarbonate hardness
- Alkalinity
- Turbidity
- Dissolved oxygen
- Suspended organic carbon

Common Ions
- Calcium
- Magnesium
- Sodium
- Potassium
- Bicarbonate
- Carbonate
- Sulfate
- Chloride
- Fluoride
- Silica

Nutrients
- Nitrate as N
- Nitrate + nitrite as N
- Total ammonia + organic nitrogen as N
- Total Phosphorus as P
- Phosphate as P

Sediment Load
- Suspended Sediment Sizing
- % < .002 m
- 8.062 m < % <0.125 m
- 0.125 m < % <0.250 m
- 0.250 m < % <0.500 m
- 0.500 m < % <1.00 m
- % > 1.00 m
- Bed Load Sizing
- % < 0.250 m
- 8.250 m < % <0.500 m
- 0.500 m < % <1.00 m
- 1.00 m < % <2/00 m
- 4.0 m < % < 8.00 m
- 8.0 m < % < 10.0 m
- 16.0 m < % < 32.0 m
- 2.0 m < % < 64.0 m
- % > 64.0 m

Trace Elements[a]
- Aluminum
- Arsenic, total and dissolved
- Beryllium
- Cadmium
- Chromium
- Copper
- Iron
- Lead
- Lithium
- Manganese
- Mercury
- Molybdenum
- Nickel
- Selenium
- Zinc

Radiochemical
- Gross alpha, suspended and dissolved
- Gross beta, dissolved and suspended
- Radium - 226, dissolved
- Natural uranium, dissolved

Trace Organics and Pesticides[b]
- PCBs
- Chlorinated Naphthalenes (water only)
- Aldrin
- Chlordane
- DDD
- DDE
- DDT
- Diazinon (whole sample)
- Dieldrin
- Endosulfan (whole sample)
- Endrin
- Ethion (whole sample)
- Heptachlor
- Heptachlor exoxide
- Lindane
- Malathion (whole sample)
- Methoxyclor
- Methyl parathion (whole sample)
- Methyl trithion (whole sample)
- Mirex (water only)
- Parathion (whole sample)
- Perthane (whole sample)
- Toxaphene
- Total Trithion (whole sample)
- 2, 4-D
- 2, 4, 5-T
- Silvex

Source: USGS 1980.

[a]Total recoverable, total suspended, and dissolved components were measured for each element except for arsenic.

[b]Unless otherwise indicated, the concentrations of the constituent in-water and in-bottom materials were measured.

TABLE 5-7

SUMMARY OF SELECTED WATER QUALITY CHARACTERISTICS OF THE NORTH PLATTE RIVER AT ORIN AND GLENROCK

Parameter[a]	Concentrations					
	Glenrock			Orin		
	Average	Minimum	Maximum	Average	Minimum	Maximum
General Constituents						
Flow, cfs	1,400	2.4	7,060	1,930	490	10,600
Water temperature, °C	12.5	0.0	27.5	11.2	0	26
pH, units	--	6.9	8.7	--	6.9	9.0
Conductivity, mhos/ m at 25°C	705	361	1,310	676	329	1,030
Total dissolved solids (sum)	453	236	963	520	410	710 (Residue at 105°C)
Suspended solids	78	11	144	845	6	62,500
Turbidity NTU				22	1	200
Total alkalinity, as $CaCO_3$	137	88	173	141	80	197
Total hardness, as $CaCO_3$	250	150	450	240	120	440
Dissolved oxygen	--	--	--	9.8	6.3	14.0
Common Ions						
Calcium	62	26	103	62	33	89
Magnesium	22	8	48	21	5.3	38
Sodium	55	20	150	53	17	110
Potassium	3.5	0.3	6.8	3.7	1.9	6.3
Iron (Dissolved)	0.06	0.0	0.2	0.06	0.0	0.49
Manganese (Dissolved)	--	--	--	0.007	0.0	0.02
Carbonate	0.3	0	10	1.0	0	12
Bicarbonate	166	107	211	171	98	240
Sulfate	203	83	479	192	61	338
Chloride	14.9	0.5	39	14	3.9	30
Fluoride	0.5	0.0	0.8	0.5	0.2	0.7
Boron	0.09	6.0	0.44	0.08	0.02	0.29
Nutrients						
Ammonia	1.3	0.8	1.5	0.02	0.0	0.05
Nitrate	1.9	0	14	1.9	0.0	18.2
Nitrite	5.9	1	9	--	--	--

Source: EPA 1981.

[a]All concentrations in mg/l unless otherwise indicated.

TABLE 5-8

RESULTS OF A SYNOPTIC WATER QUALITY SURVEY ALONG NORTH PLATTE RIVER

Constituents (mg/l)	Glenrock	Orin
Date	8/4/76	8/5/76
Flow, cfs	3,600	3,400
Total hardness	200	210
Calcium	54	55
Magnesium	16	18
Sodium	35	39
Potassium	3.4	3.7
Sulfate	160	160
Chloride	9.3	9.2
Fluoride	0.4	0.3
Silica	11	11.0
Total nitrogen as N	1.0	1.7
Organic nitrogen as N	0.53	0.67
Total kjeldahl as N	0.55	0.68
Nitrate + Nitrite as N	0.46	1.0
Total phosphorus as P	0.15	--
Trace Elements (g/l)		
Aluminum, total	2,500	5,900
Aluminum, dissolved	40	40
Antimony, total	0.0	0.0
Antimony, dissolved	0.0	0.0
Arsenic, total	3.0	2.0
Arsenic, dissolved	1.0	2.0
Beryllium, total	0.0	0.0
Beryllium, dissolved	0.0	0.0
Boron dissolved	60	70
Cadmium, total	10	10
Cadmium, dissolved	7	1
Chromium total	0.0	10.0
Chromium, dissolved	0.0	0.0
Copper, total	10	20
Copper, dissolved	6	2
Iron, total	3,200	7,000
Iron, dissolved	20	10
Lead, total	100	100
Lead, dissolved	3	1
Lithium, total	30	40
Lithium, dissolved	20	20
Manganese, total	80	160
Manganese, dissolved	0	0.0
Mercury, total	0.1	0.1
Mercury, dissolved	0.2	0.2
Nickel, total	50	50
Nickel, dissolved	3	2
Selenium, total	3	3.0
Selenium, dissolved	3	3.0
Vanadium, dissolved	0.0	0.0
Zinc, total	20	70
Zinc, dissolved	10	0.6

Source: EPA 1981.

TABLE 5-9

TRACE ELEMENT CONTENT OF THE NORTH PLATTE RIVER AT ORIN

Trace Element (mg/l)	Dissolved Avg.	Dissolved Min.	Dissolved Max.	Suspended Avg.	Suspended Min.	Suspended Max.	Total Avg.	Total Min.	Total Max.
Aluminum	19	0.0	60	515	0.0	1,500	660	0.0	2,300
Antimony	--	--	--	0.33	0.0	1.0	0.33	0.0	1.0
Arsenic	1.6	0.0	3.0	1.2	1.0	2.0	2.8	2.0	5.0
Barium	30	30	30	--	--	--	--	--	--
Beryllium	1.3	0.0	10	4.3	0.0	10	2.7	0.0	10
Cadmium	2.0	0.0	6.0	1.4	1.0	4.0	5.4	0.0	10
Chromium	1.9	0.0	10	2.5	0.0	10	2.7	0.0	10
Cobalt	3.0	3.0	3.0	--	--	--	--	--	--
Copper	4.5	2.0	15	7.4	0.0	31	13	2.0	34
Gallium	3.0	3.0	3.0	--	--	--	--	--	--
Germanium	7.0	7.0	7.0	--	--	--	--	--	--
Iron	66	0.0	490	1,200	320	3,200	290	0.0	3,200
Lead	--	--	--	11	0.0	65	43	0.0	100
Lithium	34	20	50	0.0	0.0	0.0	35	20	50
Manganese	7.3	0.0	20	53	10	120	60	20	130
Mercury	0	0.0	0.0	0.01	0.0	0.1	0.05	0.0	0.4
Molybdenum	3.8	0.0	10	1.4	0.0	4.0	3.4	1.0	8.0
Nickel	3.3	0.0	11	10	0.0	44	23	0.0	50
Selenium	4.6	0.0	11	10	0.0	4.0	5.4	2.0	12
Silver	1.0	1.0	1.0	--	--	--	--	--	--
Strontium	300	300	300	--	--	--	--	--	--
Titanium	3	3	3.0	--	--	--	--	--	--
Vanadium	4.3	0.7	11	--	--	--	--	--	--
Zinc	7.5	0	20	60	6.0	320	56	0.0	330
Zirconium									

Source: EPA 1981.

TABLE 5-10

TRACE ORGANIC AND PESTICIDE CONTENT OF THE NORTH PLATTE RIVER AT ORIN

PARAMETER	TOTAL (In Whole Water Sample) mg/l			SEDIMENT (mg/kg)		
	Avg.	Min.	Max.	Avg.	Min.	Max.
Phenols	2,800	1	7,600	--	--	--
Perthane	0.0	0.0	0.0	--	--	--
Naphthalene	0.0	0.0	0.0	--	--	--
Aldrin	0.0	0.0	0.0	0.0	0.0	0.0
Gamma-BHC	0.0	0.0	0.0	0.0	0.0	0.0
Chlordane	0.0	0.0	0.0	0.63	0.0	2.0
DDD	0.0	0.0	0.0	0.15	0.0	0.5
DDE	0.0	0.0	0.0	0.10	0.0	0.5
DDT	0.0	0.0	0.0	0.11	0.0	0.7
Dieldrin	0.0	0.0	0.0	0.04	0.0	0.1
Endosulfan	0.0	0.0	0.0	--	--	--
Endrin	0.0	0.0	0.0	0.0	0.0	0.0
Ethiun	0.0	0.0	0.0	0.0	0.0	0.0
Toxaphene	0.0	0.0	0.0	0.0	0.0	0.0
Heptachlor	0.0	0.0	0.0	0.0	0.0	0.0
Methoxychlor	0.0	0.0	0.0	0.0	0.0	0.0
PCB's	0.0	0.0	0.0	1.8	0.0	4.0
Malathion	0.0	0.0	0.0	--	--	--
Parathion	0.0	0.0	0.0	--	--	--
Diazinon	0.0	0.0	0.0	--	--	--
Methyl Parathion	0.0	0.0	0.0	--	--	--
2,4-D	0.0	0.0	0.0	0.0	0.0	0.0
2,4,5-T	0.0	0.0	0.0	0.0	0.0	0.0
Mirex	0.0	0.0	0.0	--	--	--
Silvex	0.0	0.0	0.0	0.0	0.0	0.0
Trithion	0.0	0.0	0.0	--	--	--
Methyl Trithion	0.0	0.0	0.0	--	--	--

Source: EPA 1981.

TABLE 5-11

YEARLY AVERAGE TDS LOADS FOR THE NORTH PLATTE RIVER AT GLENROCK (1961-1980)

Water Year Oct-Sept		TDS Loading (tons/month)	Yearly Load (tons)
1961		37,301	447,612
1962		43,550	522,600
1963		44,943	539,316
1964		54,610	655,320
1965		50,935	611,220
1966		51,470	617,640
1967		44,835	538,020
1968		50,431	605,172
1969		50,973	611,676
1970		43,213	518,556
1971		87,786	1,053,432
1972		47,274	566,556
1973		79,282	951,384
1974		83,738	1,006,056
1975		55,590	667,080
1976		51,826	621,912
1977		49,405	592,860
1978		56,687	680,244
1979		55,181	662,172
1980		59,234	710,808
	Averages	54,927	659,124

TABLE 5-12

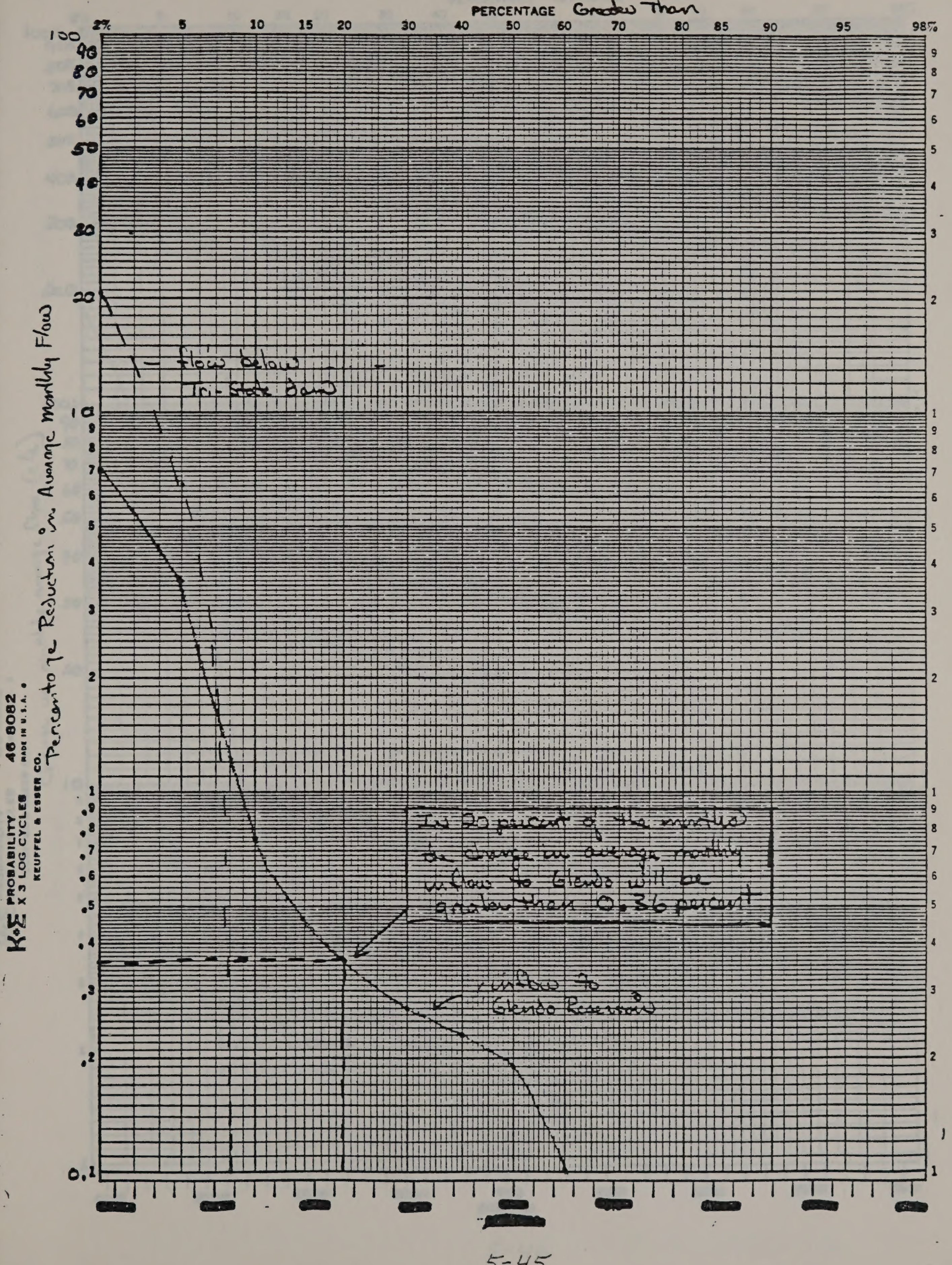
AVERAGE MONTHLY TDS LOADS FOR THE
NORTH PLATTE RIVER AT GLENROCK (1961-1980)

Month	MONTHLY TDS LOAD (tons) Avg	Min.	Max.
JANUARY	36,684	27,603	48,872
FEBRUARY	36,593	25,685	45,227
MARCH	44,847	22,237	73,008
APRIL	67,179	38,309	206,996
MAY	76,310	33,913	302,630
JUNE	67,321	33,576	190,193
JULY	67,155	40,195	124,250
AUGUST	76,679	30,200	120,568
SEPTEMBER	55,593	30,432	82,886
OCTOBER	50,378	39,160	61,900
NOVEMBER	40,569	24,736	53,087
DECEMBER	37,713	21,047	50,116

5.1 IMPACTS OF WYCOALGAS DIVERSIONS

The surface water impacts part of the technical report has not yet been completed. Refer to surface water section of PDEIS for discussion of impacts. Contained in this section, though, are probability plots showing the probability that a given impact on flows, power production and irrigation deliveries will be exceeded in any given month or year on the North Platte River (Figures 5-8 through 5-11). Table 5-13 summarizes the calculated impacts and the calculated probabilites. Figure 5-12 depicts simulated water levels in Combs Reservoir.

Figure 5-8 Calculated Probability Distribution of Percentage Change in Monthly Flows in North Platte River



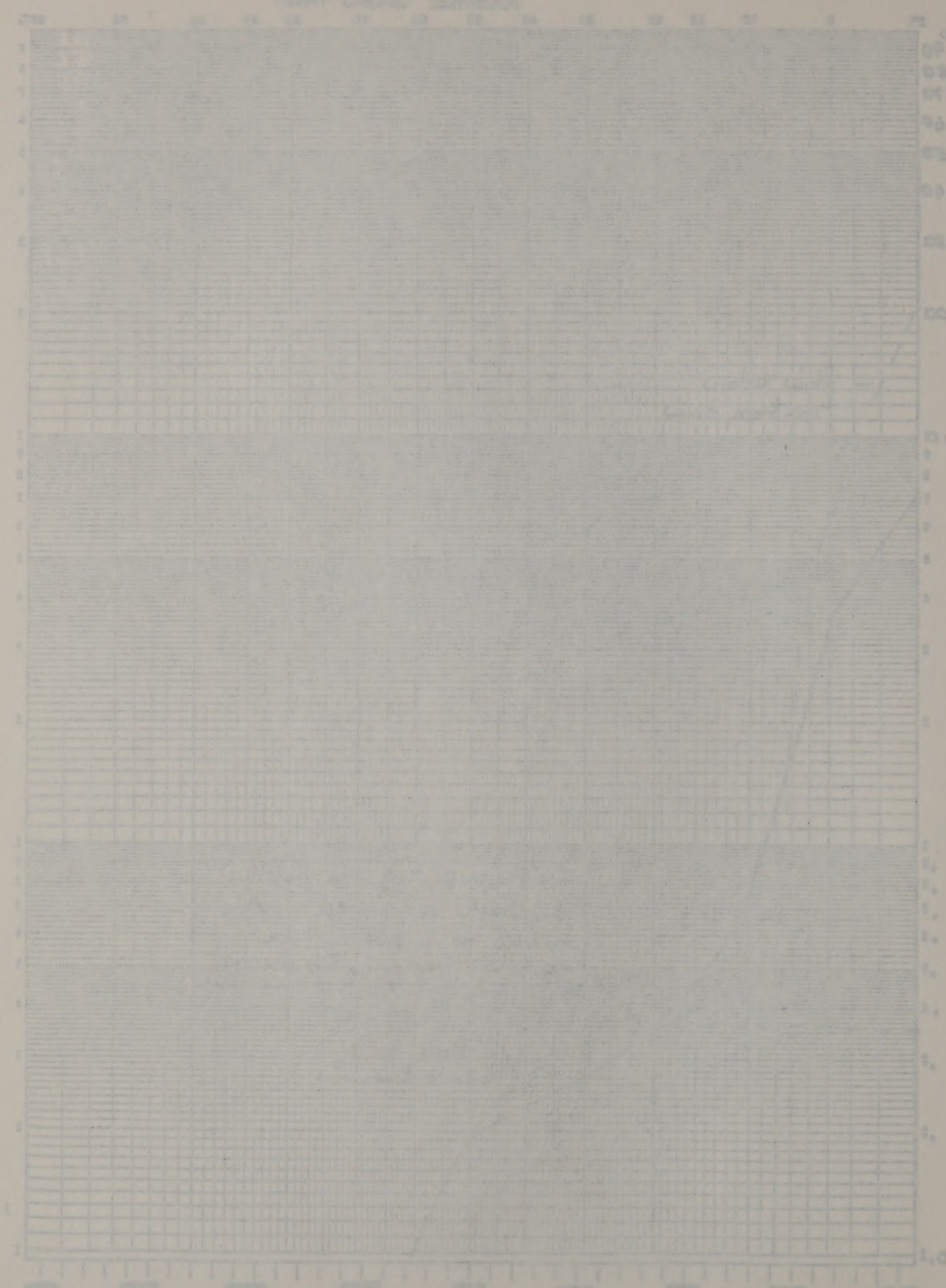


Figure ~~8~~. Calculated Probability Distribution of [illegible]
5-9 Average Flow in North Platte River.

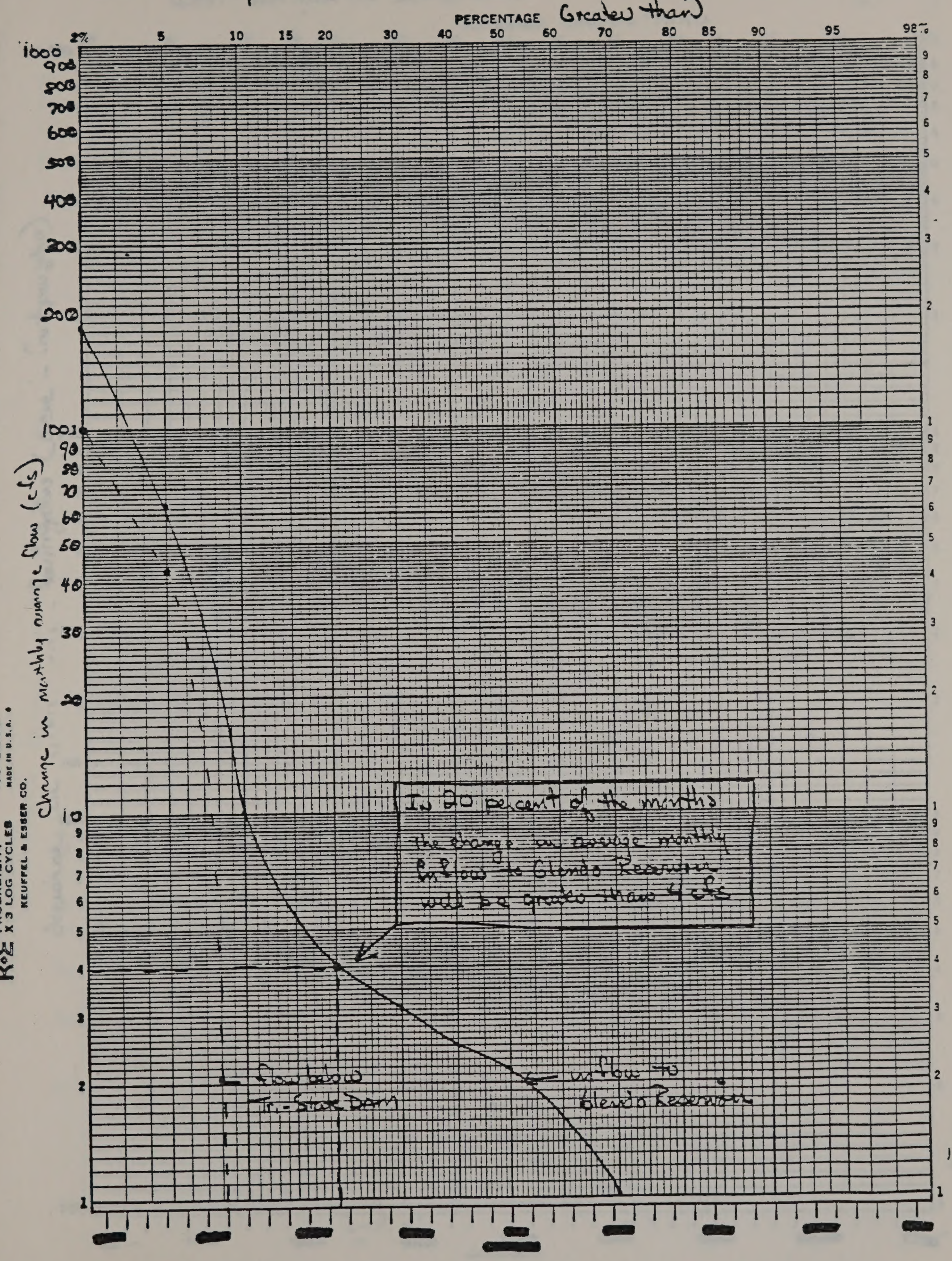


Figure 5. 5-10 Calculated Probability Distribution of Annual Reduction in Water Available for Irrigation.

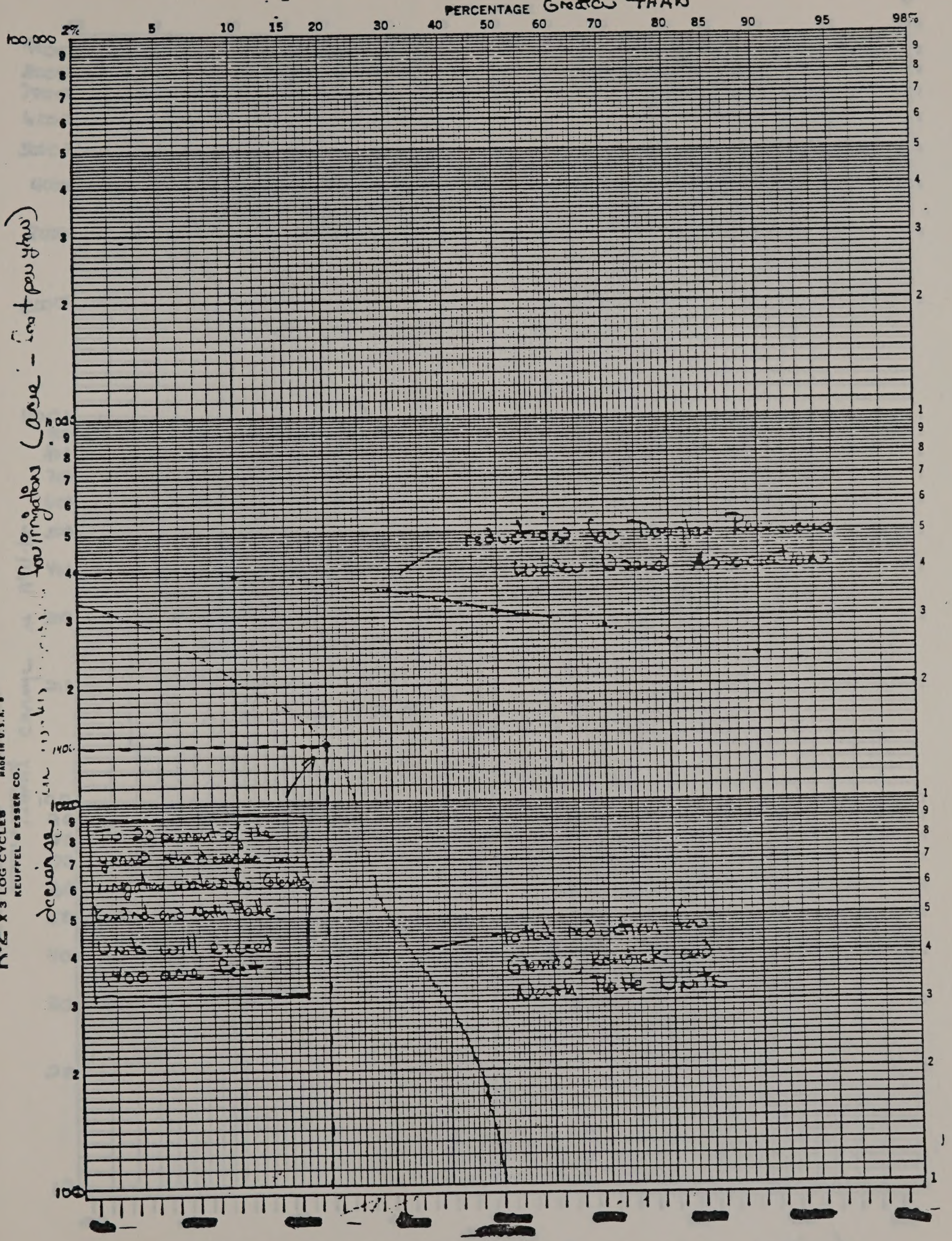


Figure # 5-11 Calculated Probability Distribution of Changes in Annual Power Production on the North Platte River in Wyoming

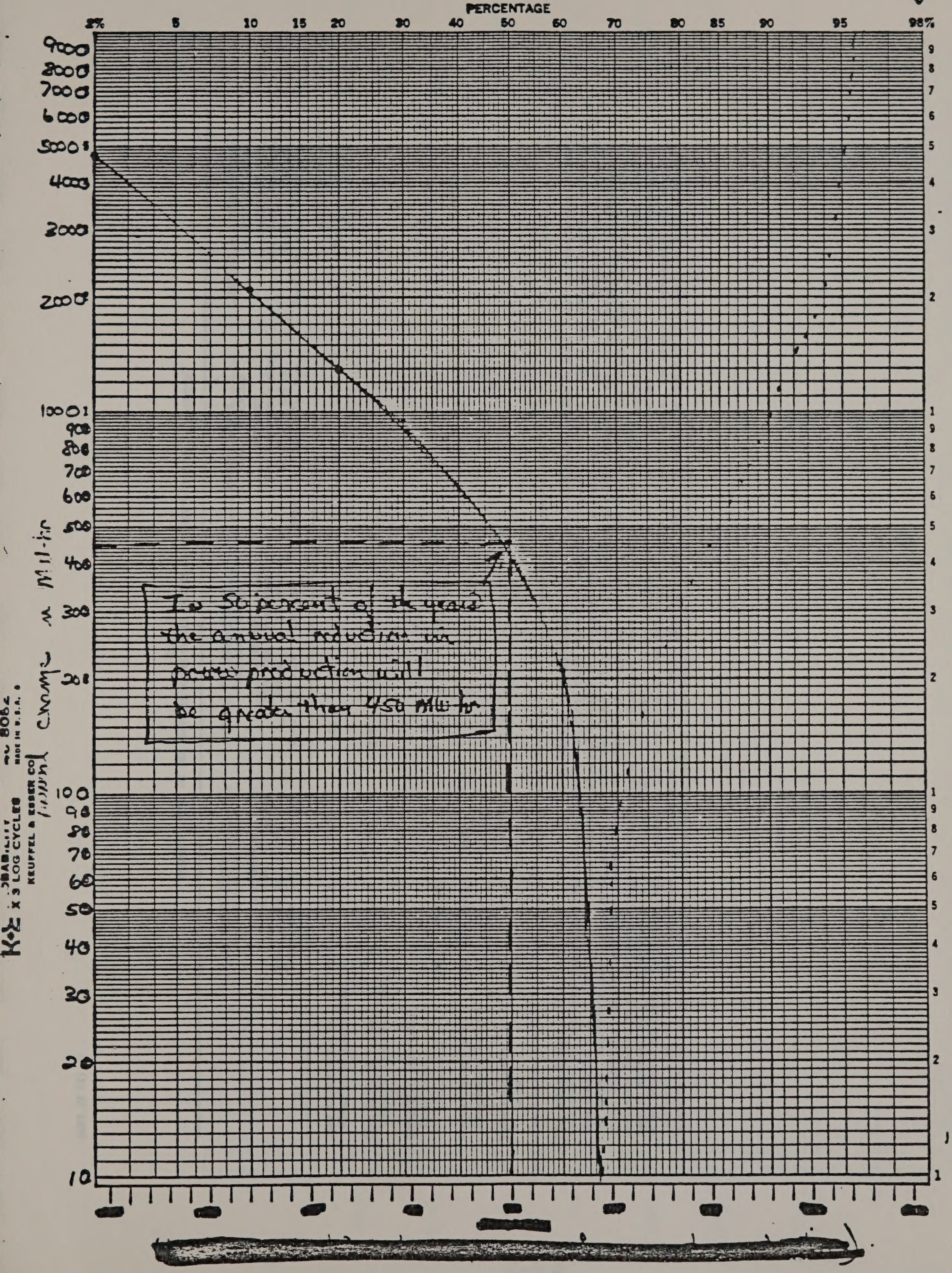


TABLE 5-13
PROBABLE EFFECT OF THE PROPOSED WATER SUPPLY SYSTEM ON THE NORTH PLATTE RIVER SYSTEM[a]

	Annual Change			Annual Percentage Change			Monthly Change			Monthly Percentage Change		
		Amount of Change expected			Percentage Change expected			Amount of Change expected			Amounted of Change expected	
	Mean Change	More than 10% of the time	More than 90% of the time	Mean	More than 10% of the time	More than 90% of the time	Mean	More than 2% of the time	More than 25% of the time	Mean	More than 2% of the time	More than 25% of the time
Flow in North Platte River above Glendo (cfs)	6.7	17.8	0.11	.44	1.2	.01	6.7	188	3.7	0.1	8.7	0.3
Flow in North Platte below Tri-State Dam (cfs)	6.0	18.0	0	2.0	5.5	0	6.0	103	0	1.1	20	0
Irrigation Deliveries (acre-feet)												
___________	540	2100		.05	0.2	0						
Douglas Water Users Association (LaPrele)	3200	3900	2400	21	30	10						
Power Generation MW-hr	850	2100	-970	0.11	0.33	0						

[a]The values listed in this table (except LaPrele irrigation deliveries) were calculated using the North Platte River Operations Model (refer to Water Supply and Yield Analysis). The model was run initially with present operating conditions and present river demands to calculate the base river flows, irrigation deliveries, and power generation for a 50 year period with climatic conditions identical to those in the period 1930-1980. A second run was then made in which WyCoalGas demands were added to the system. The river flows, irrigation deliveries, and power generation calculated in this run were then subtracted from the values obtained in the initial run to create this table. The SPSS statistical package was used to calculate the percentage reductions in the base rates, and the probabilities. The change in LaPrele irrigation deliveries was calculated using the WyCoalGas Water System Operation Model (refer to Water Supply and Yield Analysis). An initial run was made in which LaPrele Reservoir with a 20,000 acre foot pool was operated without WyCoalGas demands, and then a run was made with WyCoalGas demands. The difference between total water diverted for irrigation and total water consumed by both irrigation and WyCoalGas was calculated on a monthly basis. The change in consumptive use, as well as diversion, with the 1974 North Platte water rights were input to the North Platte River operations model to calculate the impact of WyCoalGas's proposed water use. It should be noted that the base run assumed a LaPrele demand based on a rehabilitated reservoir, not on historical demand.

Figure ~~6~~ 5-12

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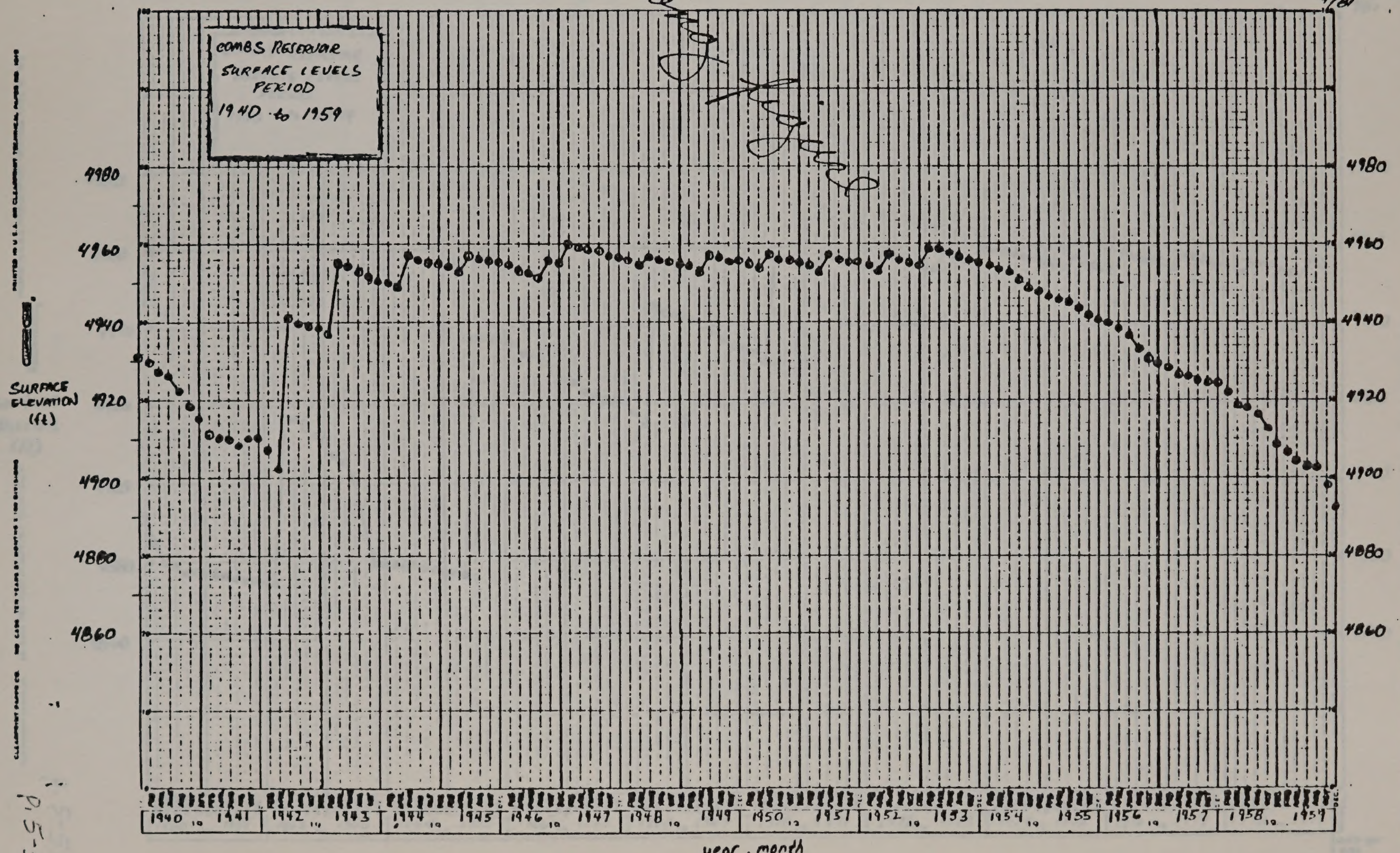

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5-12 ~~to~~ continued

Figure ~~7~~. Calculated water surface ... [illegible]

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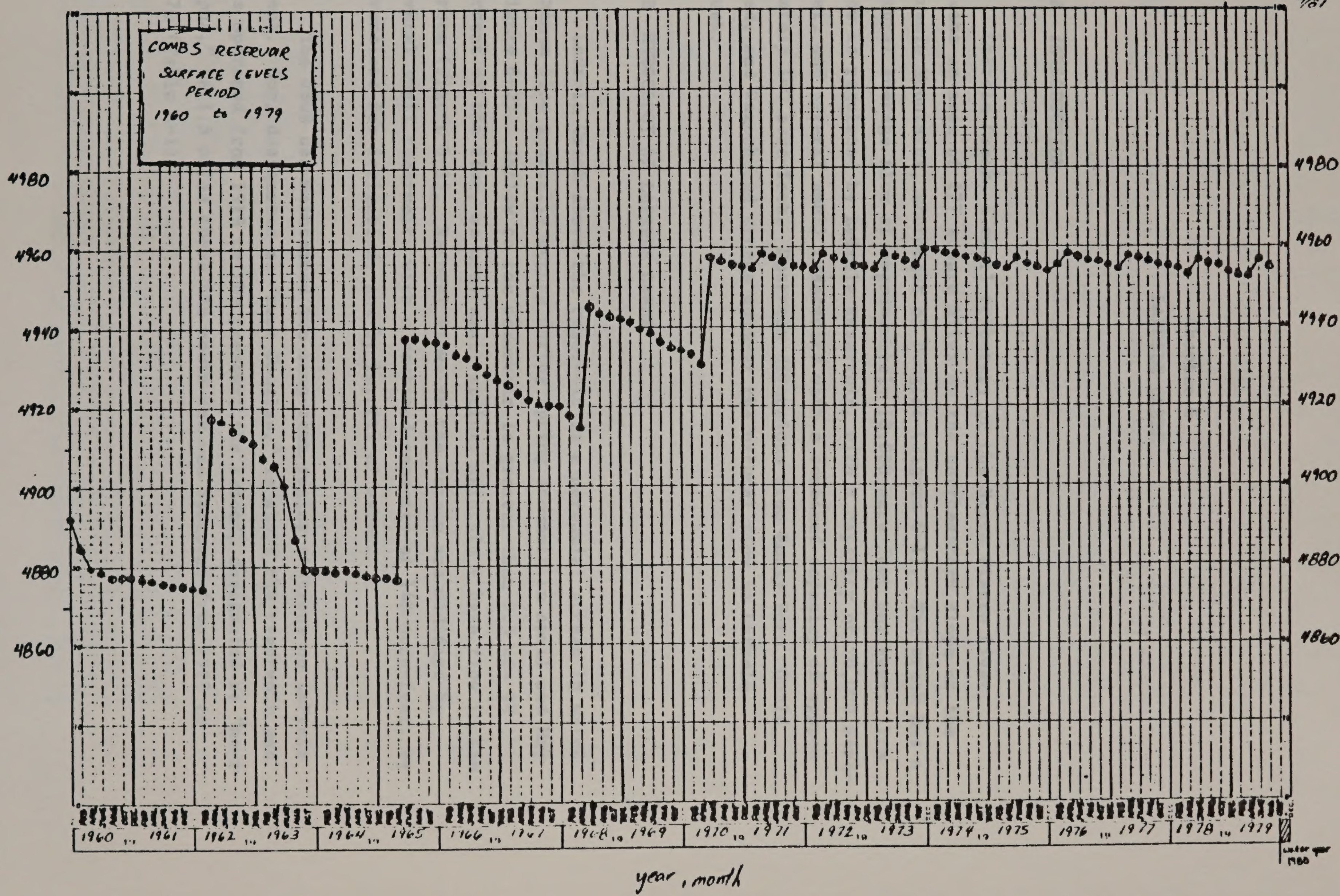

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Chapter 6
LAPRELE CREEK

6.A INTRODUCTION

LaPrele Creek, a small tributary of the North Platte River, drains an area of 177 square miles on the northeastern slope of the Laramie Mountains, southwest of Douglas (Figure 6-1). The creek has a natural average flow of approximately 18,000 acre-feet per year. Its flow is regulated by LaPrele Reservoir, with a capacity of 20,000 acre-feet, and several small reservoirs with a combined capacity of approximately 140 acre-feet. Upstream diversions from Rocky Ford, Gould, Reed, and Wagonhound creeks augment the natural flow in LaPrele Creek.

6.B HYDROLOGY OF LAPRELE CREEK

LaPrele Creek above the reservoir is a perennial stream in which maximum flow generally occurs during spring snowmelt in April and May (Figure 6-2). Inflow to the reservoir is greater than 0.5 cfs 98 percent of the time, as many small springs maintain a base flow in the stream (Figure 6-3). Natural flows in the stream are modified by several small reservoirs with a combined capacity of 140 acre-feet, by diversions for irrigation, and by imports of water.

The USGS has maintained two long-term gaging stations on LaPrele Creek. One, designated as "near Douglas," is above the reservoir and has operated from 1919 to the present; the second, designated as "near Orpha," is 1.5 miles above the mouth and was operated from 1928 to 1970 (Table 6-1).

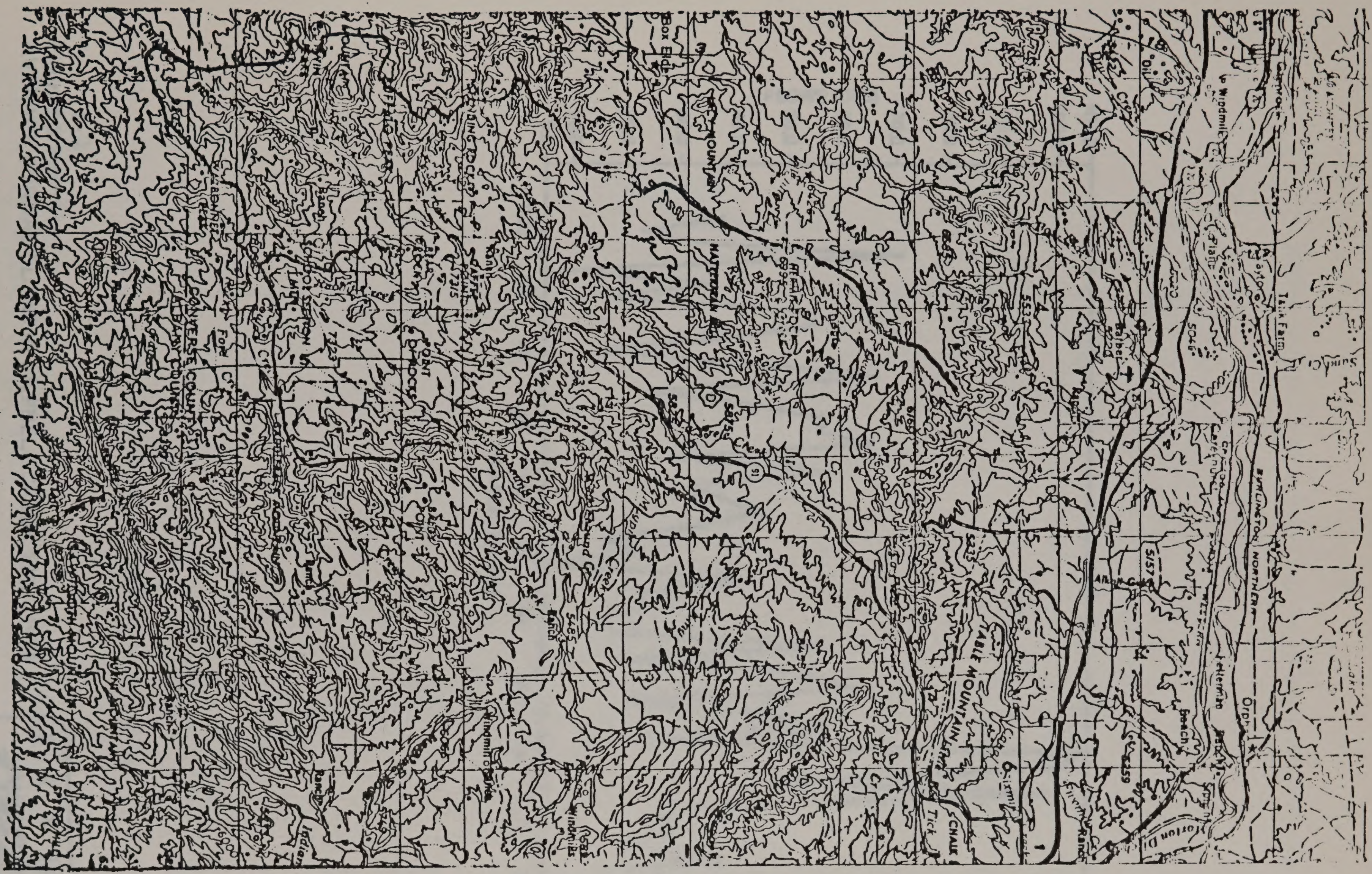

Figure 6-1 LaPrele Creek drainage basin.

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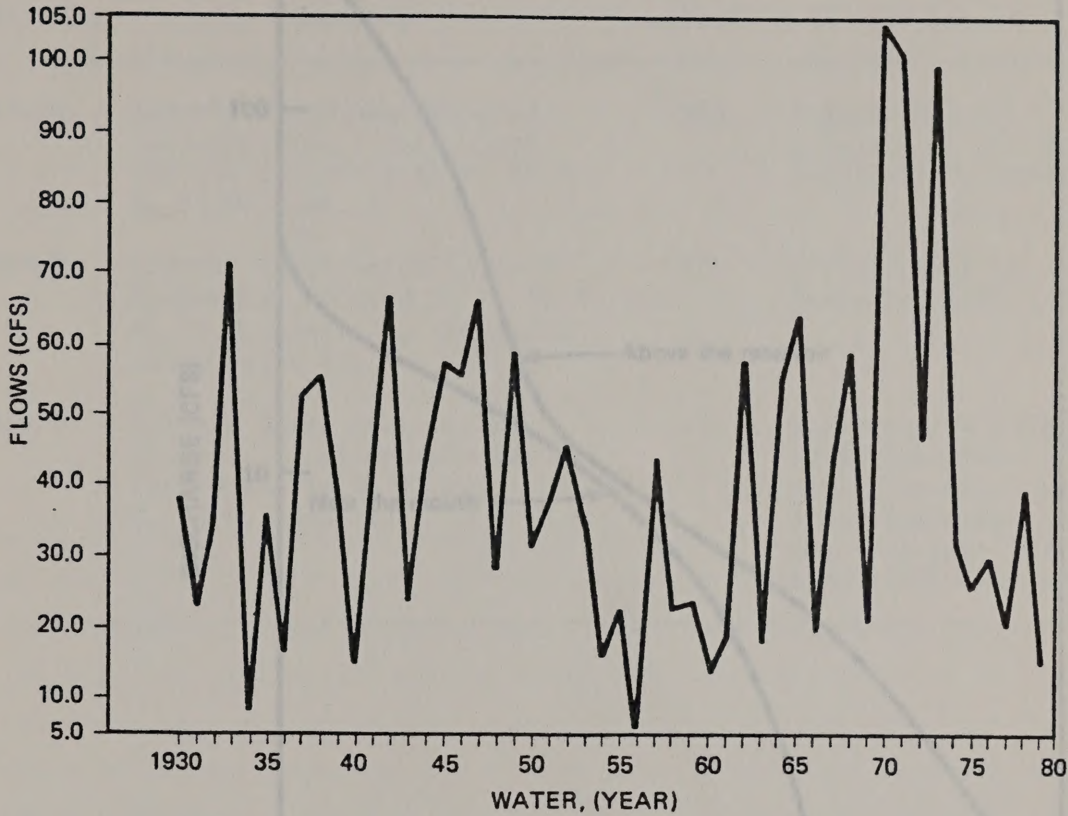
6-2

Figure 6-1



6-2
Figure ~~2.3.2-6~~
AVERAGE ANNUAL FLOWS IN LA PRELE CREEK 1930 – 1979

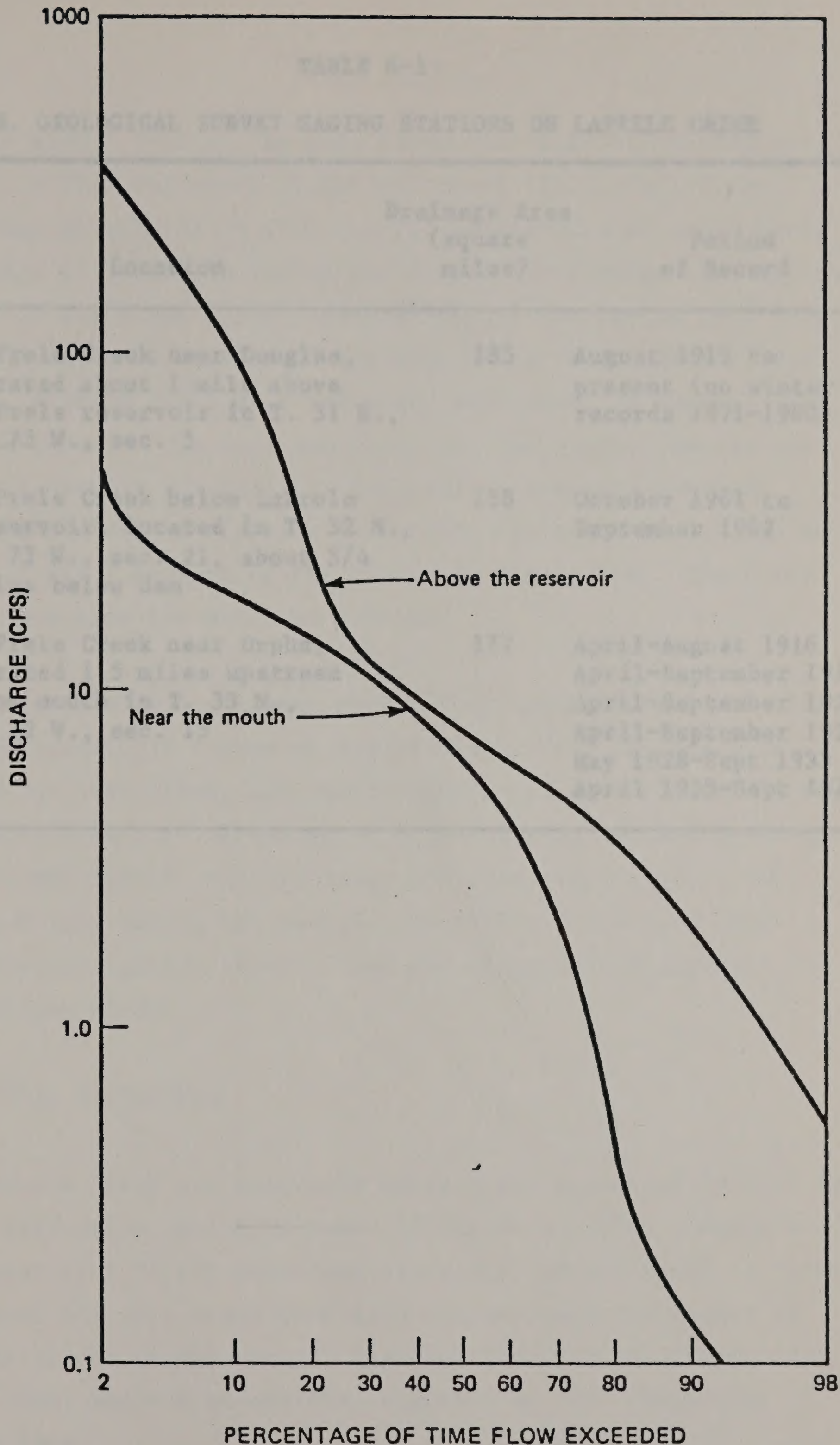


Figure ~~2.3.2-7~~ 6-3
FLOW DURATION CURVE FOR LA PRELE CREEK NEAR DOUGLAS (ABOVE THE RESERVOIR) AND ORPHA (NEAR THE MOUTH) (BASED ON 1936-1971 PERIOD OF RECORD)

TABLE 6-1

U.S. GEOLOGICAL SURVEY GAGING STATIONS ON LAPRELE CREEK

Station	Location	Drainage Area (square miles)	Period of Record
66490	LaPrele Creek near Douglas, located about 1 mile above LaPrele reservoir in T. 31 N., R. 73 W., sec. 5	135	August 1919 to present (no winter records 1971-1980)
66492	LaPrele Creek below LaPrele Reservoir, located in T. 32 N., R. 73 W., sec. 21, about 3/4 miles below dam	158	October 1961 to September 1962
66495	LaPrele Creek near Orpha, located 1.5 miles upstream from mouth in T. 33 N., R. 72 W., sec. 15	177	April-August 1916 April-September 1918 April-September 1923 April-September 1924 May 1928-Sept 1933 April 1935-Sept 1970

Average annual flow at the gage above the reservoir during the period 1936 to 1970 was about 25,000 acre-feet (34.5 cfs) (Figure 6-2). Average annual runoff from the 135-square-mile drainage basin above the gage is about 3.5 inches per year. The average annual flow near the mouth was about 7,340 acre-feet during the period 1936-1970, which is only about 30 percent of the flow above the reservoir; see Figure 6-4. Natural flows near the mouth were about 10 percent greater than flows at the upstream gage, but the excess flow is now consumed by reservoir evaporation, irrigation, and out-of-basin diversions (WPRS 1969a). LaPrele Creek near the mouth has a flow of less than 0.1 cfs 7 percent of the time; see Figure 6-3. The 7-day 5-year low flow near the mouth is 0.0 cfs.

The irrigation of lands with waters from LaPrele Creek has also affected the hydrologic regime of Alkali Creek, Five and Six Mile creeks, and Bed Tick Creek, all small tributaries of the North Platte River. About 46 percent of the water diverted from LaPrele Creek by the Westside and LaPrele ditches below the reservoir (about 7,240 acre-feet per year during the period 1936-1970), flows into these tributaries as irrigation return flows and eventually discharges to the North Platte River.

6.C HISTORICAL BACKGROUND

The LaPrele Ditch and Reservoir Company was organized in 1905 to develop an irrigation system to serve 27,000 acres. The company's plan consisted of a 20,000 acre-foot reservoir LaPrele Creek, a diversion dam about one mile downstream from the dam, and two canals to convey water to the service area. Construction of these facilities started in 1906, and was essentially complete by 1909 (Bureau of Reclamation 1969).

Average Monthly Flows, LaPrele Creek at mouth, 1965-1974

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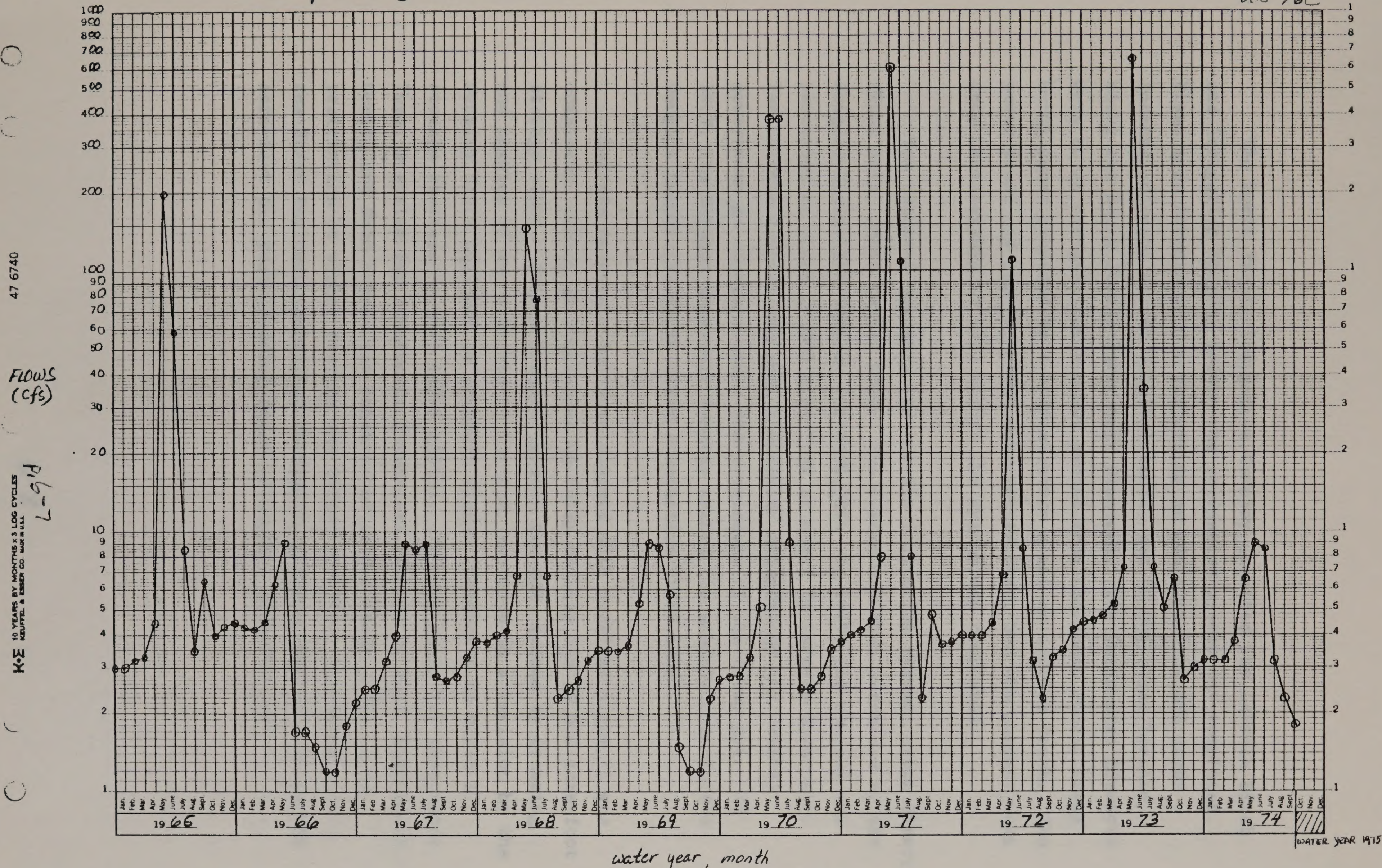


Fig. 7

The North Platte Irrigation Company acquired the LaPrele Ditch and Irrigation Company before the irrigation system was completed. Plans were formulated for irrigating an additional 10,000 acres located adjacent to the original lands, and 40,000 acres located along the North Platte River near Glenrock. The lands near Glenrock were to be irrigated with water pumped from the North Platte River using power provided by a hydroelectric plant on LaPrele Creek. The power plant and pumping plant were constructed, but the company went into receivership in 1912 before the system was completed.

The receiver operated the LaPrele irrigation system, using direct flows only, until August 1918. The system was then purchased by the Douglas Reservoirs Company for $150,000. In 1919, the company was permitted to store 20,000 acre-feet of water in LaPrele Reservoir. The LaPrele Project was soon thereafter accepted by the federal government as complete under the provisions of the Carey Act. In 1923, the Douglas Reservoir Company turned the project over to the Douglas Reservoirs Water Users Association (WPRS 1969).

LaPrele Reservoir has been plagued with problems since it was completed, making it impossible to fully utilize its 20,000 acre-foot storage right. Severe leakage through the dam, caused by freezing and thawing of wet concrete in the dam, resulted in a decision by the Wyoming State Engineer to prohibit winter (October 1 to March 1) storage starting in 1925 (WPRS 1969b). To compensate for this water loss, a system for transbasin diversions from Rocky Ford, Wagonhound, Gould, and Reed creeks was constructed in the early 1930s. The restriction on winter storage was lifted in 1956. In February 1971, the State Engineer restricted storage in LaPrele Reservoir to 10,000 acre-feet per year (Wyoming Board of Control Order No. 20).

The Douglas Reservoirs Water Users Association signed an agreement on May 18, 1974 with Panhandle Eastern Pipeline Company whereby Panhandle Eastern agreed to pay for repairing the dam in exchange for the right to purchase up to 5,000 acre-feet per year from the association. Wyoming Board of Control Order No. 20, dated May 19, 1975, amended the water rights permits for LaPrele Reservoir to permit the storge of water for industrial use. Dam rehabilitation was completed in 1979, and the full 20,000 acre-foot storage capacity was utilized in water year 1980. Even after rehabilitation, dam seepage is estimated to be about 12 cfs at full capacity (Wyoming State Engineer 1980).

6.D WATER USE AND WATER RIGHTS

Waters from LaPrele Creek are used to irrigate about 17,525 acres, of which about 10,300 acres (58 percent) are lands of the Douglas Reservoirs Water Users Association. Additionally, about 4,600 acres are irrigated with direct flow diversions above LaPrele Reservoir and about 1,470 acres with direct flow diversion below LaPrele Reservoir. In addition, about 1,150 acres are irrigated with waters conveyed under contract by the distribution system of the Douglas Reservoirs Water Users Association to lands that are not association lands (referred to as "carrier lands").

Douglas Reservoirs Water Users Association lands are irrigated with waters diverted about 1 mile below LaPrele Dam into the LaPrele Main Ditch and the West Side Ditch. Only about 8 percent of the association lands are in the LaPrele Creek drainage basin; the remainder are in the drainage basins of Alkali, Five Mile, Six Mile, and Bed Tick creeks, all of which are small tributaries of the North Platte River.

The irrigated lands in the LaPrele Creek basin that are not in the Douglas Reservoirs Water Users Association have water rights senior to those of the association. The senior water rights include those with pre-1905 priority dates for irrigating 7,683 acres upstream of La Prele Reservoir, those with 1878-1908 priority dates for irrigating 1,276 acres downstream of LaPrele Reservoir, and those with 1884-1907 priority dates for irrigating 1,033 acres of carrier lands. The Douglas Reservoirs Water Users Association has storage rights with priority dates of 1905 and 1909 for storage of 20,000 acre-feet of water, and direct diversion rights for irrigating 11,255 acres with a 1909 priority date. The association also has direct flow rights of 5.50 cfs with a 1931 priority date for the transbasin diversion from Reed, Gould, and Wagonhound creeks via the Downey Park System.

The original storage permits for LaPrele Reservoir were amended at the request of the Douglas Reservoirs Water Users Association by Board of Control Order No. 20, May 19, 1975. The major stipulations in Board of Control Order No. 20 were:

- No water right on LaPrele Creek shall be injured.
- Original permit for LaPrele Reservoir shall be amended to permit industrial use, upon completion of LaPrele Dam rehabilitation by Panhandle Eastern.
- Panhandle Eastern is authorized to divert up to 5,000 acre-feet per year, to be conveyed from LaPrele Reservoir down LaPrele Creek to the North Platte River and down the North Platte River to a diversion point to the proposed Combs Reservoir.

- Panhandle releases will be limited to 2,500 acre-feet during the period October 1 through April 30.

- In the event of shortages during the period May 1 through September 30, water shall be apportioned 25 percent to Panhandle and 75 percent to the association.

- All dam leakage will be charged to Panhandle.

- All water delivered to Panhandle by the association shall be subtracted from Panhandle's annual entitlement of water from LaPrele Reservoir.

6.E WATER AVAILABILITY

The quantities of water historically diverted by the Douglas Reservoir Water Users Association have not been recorded (WPRS 1969b). Operation studies have been conducted by WPRS (1969b) and Banner Associates (1981) to estimate the historic supply available to the association. WPRS (1969b) estimated water supplies during the period 1947-1966. The WPRS report states: "Historically the overall supply on the LaPrele Project has been poor. On an annual average basis, only 37 percent of the requirements have been met. No one year has had a full supply, and during only two years have 75 percent or more of the requirements been met. Contrasted to this, there were nine years in which 30 percent or less was met and 16 years in which the supply met less than 60 percent." Total diversions for the period of the study averaged 17,900 acre-feet per year. Total consumptive use on association lands was estimated to average about 9,300 acre-feet per year.

An operation model of LePrele Reservoir and creek was constructed by Banner Associates (1981) to determine the historic availability of water to WyCoalGas, and to estimate the historic quantities of water available for irrigation on lands of the Douglas Reservoir Water Users Association and on downstream lands with senior water rights. The model has also been used to estimate historic flows in LaPrele Creek near the mouth, and total consumptive use on association lands (Table 6-2). The details of the operations model are discussed in Appendix B.

In the Banner study, diversions by the Douglas Reservoir Water Users Association from LaPrele Reservoir during the period 1930-1979 were calculated to average 17,410 acre-feet per year, and ranged from a low of 1,100 acre-feet in 1956 to a high of 28,490 in 1937. Even in 1937, only 83 percent of the irrigation demand was met. Total consumptive use by the association was calculated to average 9,730 acre-feet per year.

Assuming that the WyCoalGas demand had existed during the period 1930-1979, and that LaPrele Reservoir had been operated according to Board of Control Order No. 20, water available to WyCoalGas from LePrele Reservoir during that period was calculated to average 4,610 acre-feet per year, and to range between 2,400 and 4,860 acre-feet per year.

6.F WATER QUALITY

The chemical quality of LaPrele Creek above LaPrele Dam is very good, but downstream of the dam, irrigation return flows degrade surface water quality, as Table 6-3 shows. The water in the creek above the reservoir is a moderately hard, calcium bicarbonate water, low in

TABLE 6-2

CALCULATED HISTORICAL WATER AVAILABILITY FROM LAPRELE RESERVOIR DURING PERIOD 1930-1979 [a]

	Average Annual (acre-feet)	Maximum Yearly (acre-feet)	Minimum Yearly (acre-feet)
Water Diverted by Association	17,410	28,490	1,100
Water Consumed by Association	9,730	21,540	-3,470
Water that could have been Diverted by WyCoalGas [b]	4,610	4,860 [c]	2,400

[a] Calculated by Banner Associates 1981.

[b] This assumes that WyCoalGas demand existed during period 1930-1979, and that LaPrele Reservoir operated according to Board of Control Order #20.

[c] Available supply exceeded 4,800 acre-feet in 28 of the 50 years.

TABLE 6-3

LAPRELE CREEK WATER QUALITY

Constituents[a]	Date: 7/27/65 Location: Lat. 42° 43' 50" Long. 105° 36' 50" Below LaPrele Reservoir	6/28/79 Lat. 42° 50' 58" Long. 105° 29' 16" At Mouth at Orpha
Flow, cfs	129	8.93
Temperature, °C	16.1	23.1
pH, units	7.2	8.6
Conductivity, μmhos/cm	241	610
Total dissolved solids	182 (residue at 180°C)	400 (sum of dissolved constituents)
Total alkalinity (as $CaCO_3$)	-	140
Total hardness (as $CaCO_3$)	95	200
Noncarbonate hardness (as $CaCO_3$)	-	59
Calcium	26	50
Magnesium	7.1	18
Sodium	9.5	51
Potassium	4.4	4.4
Sodium adsorption ratio	0.4	1.6
Carbonate	-	-
Bicarbonate	122	-
Chloride	2.8	10.0
Sulfate	18.0	170
Silica	57	12
Bromide	0.17	-
Fluoride	0.30	0.40
Iron	0.02	-
Total Kjeldahl nitrogen (as N)	-	0.51
NO_2 and NO_3 (as N)	-	0.03
Total phosphorus (as PO_4)	-	0.15
Total phosphate (as PO_4)	-	0.15
Selenium (as P)	-	0.002
Boron	0.03	-

Source: EPA 1981.

[a]All concentrations in mg/l unless otherwise indicated.

boron and sodium absorption ratio and excellent for irrigation. Downstream of LaPrele Dam, the water is a mixed calcium sodium sulfate type. Water quality in lower Alkali Creek, lower Five Mile Creek, and lower Bedtick Creek, whose flows are primarily derived from irrigation return flows from the LaPrele project, are listed in Table 6-4.

TABLE 6-4

AVERAGE WATER QUALITY OF LAPRELE CREEK AND STREAMS DRAINING DOUGLAS WATER USERS ASSOCIATION LANDS NOVEMBER 1966 TO MAY 1967

1	Upper LaPrele Creek at Gage	Lower LaPrele Creek at Gage	Lower Alkali Creek	Lower Five Mile Creek	Lower Bed-Tick Creek
Na	14	111	478	348	122
Ca	39	36	32	19	55
Mg	7	6	9	6	16
K	5	12	24	23	12
HCO_3	177	289	407	563	165
SO_4	38	155	866	363	343
Cl	4	11	24	35	16
TDS	194	480	1,633	1,071	644

Average concentration of seven samples taken at each location during the period November 1966 to May 1967 by U.S. WPRS (1969).

Chapter 7
PLANT SITE

7.A. SURFACE WATER

The proposed plant site is located on a topographic high that forms the divide between the Willow Creek and Little Lightning Creek drainage basins. Willow Creek and Little Lightning Creek are tributaries of Lightning Creek, which flows into Lance Creek, which flows into the Cheyenne River. The site is relatively flat, and no surface water bodies or conspicuous stream channels occur on the site. The small channel of a tributary of Little Lightning Creek, and an ephemeral stock pond, are located about 1/4 mile southwest of the site. Willow Creek is located about 1 mile east of the plant site. Surface water flow occurs as overland flow, but surface flows are infrequent since the surface soils are sandy with moderate infiltration rates. Annual average sediment yield from the plant site is likely in the range 0.05 to 0.25 acre-foot per square mile (Hadley and Schumm 1961).

Previous water quality monitoring efforts have involved chemical analyses of samples from a small pond about 1/4 mile south of the plant site and from tributaries of Lightning Creek. The chemical quality of the pond water in September 1973 is shown in Table 7-1. This water is a sodium-sulfate type, low in total dissolved solids, and suitable for irrigation and stock watering. The very high quality probably indicates that little or no ground-water inflow into the pond was occurring, and that the water was collected soon after a summer thundershower before significant concentration by evaporation occurred.

TABLE 7-1

WATER QUALITY IN POND SOUTH OF PLANT SITE[a]

Water Quality Parameters[b]	Concentration
General Constituents	
Water temperature (°C)	13.5
pH, units	9.8
Total dissolved solids, calculated	183
Turbidity (JTU)	20
Total alkalinity (as $CaCO_3$)	30
Total hardness (as $CaCO_3$)	70
Dissolved oxygen	10.1
Common Ions	
Calcium[c]	17
Magnesium[c]	7
Potassium[c]	6
Sodium[c]	30
Iron	0.5
Manganese	0.017
Carbonate[d]	7.3
Bicarbonate	22
Sulfate	100
Chloride	2.5
Nitrate (as N)	0.45
Fluoride	0.33
Trace Elements	
Arsenic	0.008
Barium	0.007
Cadmium	<0.005
Chromium	0.003
Copper	0.05
Lead	0.08
Mercury	<0.001
Selenium	<0.01
Silver	<0.006
Zinc	0.013

[a] This water sample was collected during September 1973 from a small pond located 1/4 mile south of the plant site, in the NW1/4SW1/4 sec. 34, T. 35 N., R 70 W., on a first-order tributary of Little Lightning Creek. Approximate surface area was 1.0 acre.

[b] All concentrations in mg/l unless otherwise indicated.

[c] Estimated from knowledge of total hardness, total meq/l of anions add Ca/Mg and Na/K ratios.

[d] Estimated from total meq/l for both bicarbonate and carbonate.

Chemical analyses of the water found in a tributary of Little Lightning Creek and in Willow Creek in 1975 near the site are listed in Table 7-2; Figure 7-1 shows sampling locations. These waters are very low in total dissolved solids and appear to be suitable for most uses, including irrigation, stock watering, and domestic consumption. The very low total dissolved solids content probably indicates little or no ground-water contribution to these runoff waters. The concentrations of selected elements in sediment collected from the tributary of Little Lightning Creek during April 1975 and from a composite of soil samples taken from the plant site are shown in Table 7-3.

Selected characteristics of the chemical quality of Lightning Creek downstream from the plant site are illustrated in Table 7-4. Seepage runs done during October 1978 indicate that dissolved solids increase in the downstream direction. A more complete chemical analysis on a sample obtained in June 1978 near the confluence with Lance Creek shows the water to be an extremely hard sodium sulfate type water, suggesting that water inflow is a large component of the total flow.

Overall chemical quality is poor further downstream, as measured at Lance Creek near Riverview. Lance Creek collects drainage mainly from Lightning Creek, Crazy Woman Creek, Cow Creek, and Dogie Creek. The average chemical quality for the water years 1977-1979 for selected constituents is shown in Table 7-5. The average concentrations of TDS and conductivity for this predominantly sodium sulfate water are high; the lowest concentrations are associated with the highest flows. Trace element concentrations are low.

TABLE 7-2

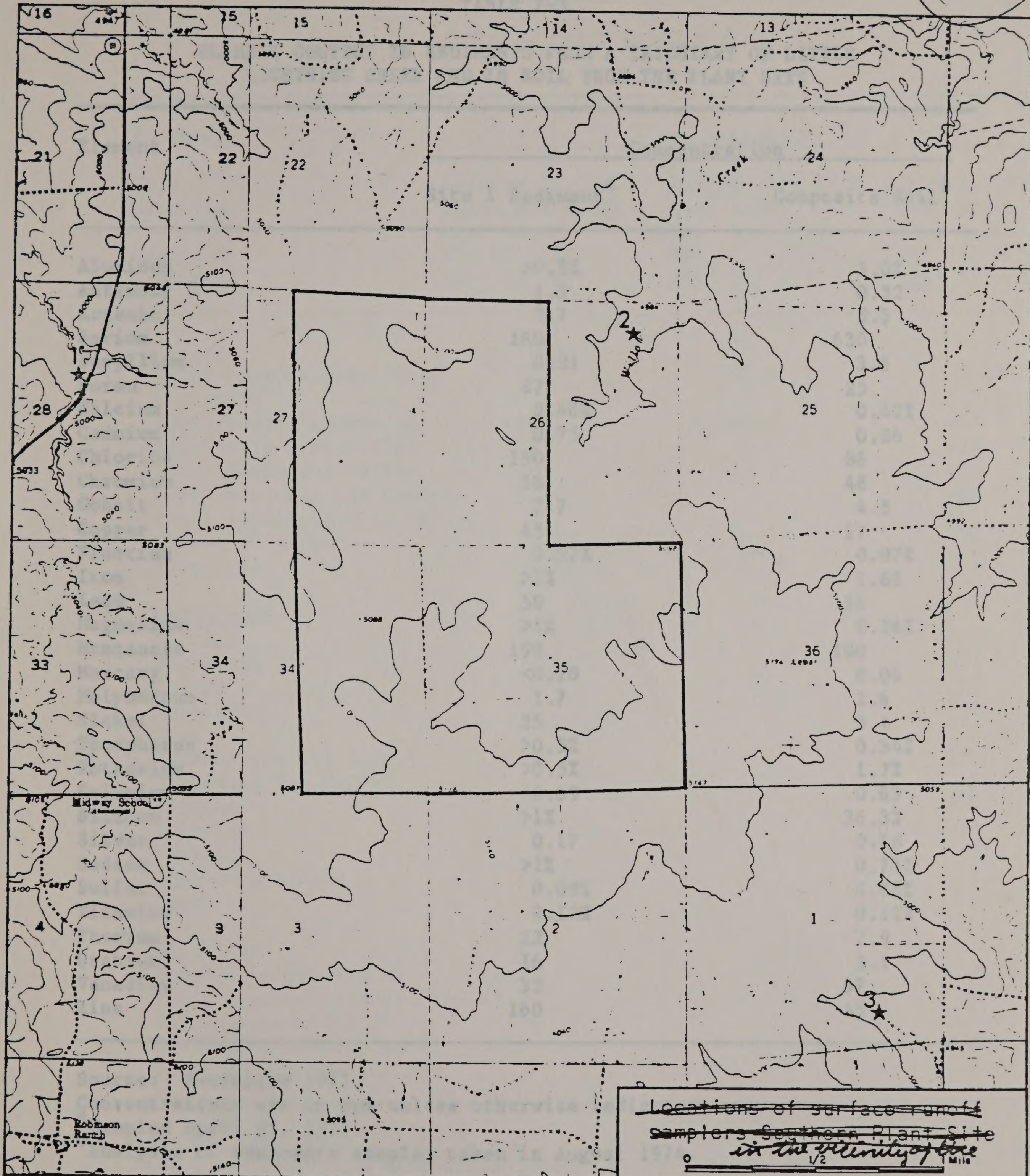
WATER QUALITY IN STREAMS NEAR THE PLANT SITE

Parameter	Concentrations[a]		
	Site 1 Tributary of Little Lightning Creek		Site 2 Willow Creek
	4/25/75[b]	6/20/75	6/20/75[c]
Conductivity (µmhos/cm)	-	81	91
Total dissolved solids	44	74	88
Calcium	5	6	3
Magnesium	3	2	2
Sodium	2	11	20
Potassium	8	10	8
Iron	-	0.38	3.3
Manganese	-	0.002	0.019
Carbonate	0	0	0
Bicarbonate	34	44	37
Sulfate	7	21	35
Chloride	2	2	2
Silicon	-	3.4	>10
Phosphorus	-	0.27	0.058
Aluminum		0.37	2.0
Arsenic		0.005	0.002
Barium		0.015	0.052
Bromine		0.016	0.007
Cadmium		-	0.001
Chromium		0.001	0.027
Cobalt		-	0.001
Copper		0.051	0.033
Lead		0.001	0.006
Molybdenum		0.001	0.002
Nickel		0.003	0.010
Selenium		<0.001	<0.001
Silver		-	0.014
Strontium		0.025	0.038
Vanadium		0.005	0.012
Zinc		0.55	0.73

Source: Metronics 1975.
[a] Concentrations are mg/l unless otherwise indicated.
[b] Water collected during snowmelt by an inplace sampling jar.
[c] Water collected after a rain event by an inplace sampling jar.
[d] Location of sampling points shown in Figure 7-11.

Figure 7-1~~5~~ Locations of water quality sampling points

hold,



~~Figure 2~~

Figure 7-1 Sampling Stations

~~(note: this figure should be combined w/ figure 10)~~

TABLE 7-3

ELEMENT CONTENT IN SEDIMENTS FROM A TRIBUTARY OF LITTLE LIGHTNING CREEK AND IN SOIL FROM THE PLANT SITE

Element	Concentration	
	Site 1 Sediment[a]	Composite Soil[b]
Aluminum	>0.5%	3.0%
Antimony	1.3	0.32
Arsenic	5.7	5.3
Barium	160	630
Beryllium	0.21	3.6
Boron	87	25
Calcium	0.46%	0.42%
Cadmium	0.75	0.86
Chlorine	190	86
Chromium	56	48
Cobalt	7.7	4.5
Copper	45	17
Fluorine	0.27%	0.07%
Iron	>1%	1.6%
Lead	50	36
Magnesium	>1%	0.26%
Manganese	190	100
Mercury	<0.10	0.06
Molybdenum	1.7	2.6
Nickel	25	3.4
Phosphorus	>0.5%	0.34%
Potassium	>0.5%	1.7%
Selenium	0.69	0.63
Silicon	>1%	36.3%
Silver	0.17	0.18
Sodium	>1%	0.73%
Sulfur	0.09%	0.08%
Titanium	0.12%	0.12%
Thorium	22	7.9
Uranium	16	3.1
Vanadium	32	37
Zinc	160	45

Source: Metronics 1975.
Concentrations are in ppm unless otherwise indicated.
[a] Sampled April 25, 1975.
[b] Analysis of composite samples taken in August 1974.

TABLE 7-4

LIGHTNING CREEK WATER QUALITY

Parameter[a]	Concentration		
Date	October 12, 1978	October 11, 1978	June 7, 1978
Location	Below Box Creek Near Junet	Near Mouth Near Cow Creek	Near Mouth Near Lance Creek
Latitude	43° 07' 18"	43° 13' 46"	43° 14' 00"
Longitude	105° 00' 23"	104° 37' 22"	104° 37' 25"
General			
Water temperature, °C	9.5	15.5	16.0
pH, units	-	-	7.8
Conductivity, μmhos/cm	1,400	3,200	1,900
Total dissolved solids	-	-	1,430
Total suspended solids	-	-	1,470
Total hardness (as $CaCO_3$)	-	-	680
Total alkalinity (as $CaCO_3$)	-	-	220
Dissolved oxygen	-	-	8.0
Flow, cfs	0.12	0.36	18
Common Ions			
Calcium	-	-	150
Magnesium	-	-	74
Sodium	-	-	210
Potassium	-	-	10
Iron	-	-	0.02
Bicarbonate (as $CaCO_3$)	-	-	270
Carbonate (as $CaCO_3$)	-	-	0
Sulfate	-	-	830
Chloride	-	-	14
Fluoride	-	-	0.5
Dissolved silica	-	-	7.5
Boron	-	-	0.08
Nutrients			
Total nitrogen (as N)	-	-	0.79
Total organic nitrogen (as N)	-	-	0.67
Total ammonia (as N)	-	-	0.03
Nitrate + Nitrite (as N)	-	-	0.09
Total Phosphorus (as P)			0.01

Source: USGS 1980.
[a]All constituents in mg/l unless otherwise indicated.

TABLE 7-5

LANCE CREEK WATER QUALITY
(Near Riverview, T. 39 N., R. 62 W., sec. 14)

Parameter[a]	Concentration		
	Average	Minimum	Maximum
Flow, cfs	-	0.0	609
pH, units	-	7.3	8.3
Water temperature, °C	-	0.0	28
Conductivity, μmhos/cm	3,500	560	7,500
Total dissolved solids	2,590	367	4,680
Hardness (as $CaCO_3$)	860	180	1,500
Alkalinity (as $CaCO_3$)	290	80	407
Calcium	212	44	370
Magnesium	78	17	150
Sodium	510	44	900
Potassium	14	6.3	18
Bicarbonate (as $CaCO_3$)	350	98	496
Sulfate	1,500	190	3,000
Chloride	100	9.9	170
Boron	0.18	0	0.3
Fluoride	0.6	0.4	0.9

Source: USGS 1978, 1980.
[a]All units in mg/l unless otherwise indicated.

7.B. GROUND WATER

The major water-bearing strata in the vicinity of the plant site are the sandstone beds in the Wasatch and Fort Union formations. All shallow domestic and stock wells in the vicinity of the plant site are completed in the Wasatch Formation, and a few deep wells are completed in the Fort Union Formation; well locations are shown in Figure 7-2. Well yields range from a few to over 100 gallons per minute. The Wasatch Formation, which may be up to 500 feet thick at the plant site, and the Fort Union Formation, which may be up to 2500 feet thick at the site, consist of lenticular, fine to coarse-grained sandstones, claystones, and siltstones; geologic cross-sections are shown in Figures 7-3 and 7-4. Water levels at the plant site are about 100 feet below land surface.

The horizontal hydraulic conductivies of the Wasatch and Fort Union formations have not been tested at the site, but they are typically in the range of 0.1 to 20 gallons per day per square foot (BLM 1979). Vertical hydraulic conductivities in the Wasatch and Fort Union formations are generally several areas of magnitude less than the horizontal hydraulic conductivities.

A potentiometric map of the Wasatch Formation in the vicinity of the plant site was constructed from water levels recorded on drillers' logs; see Figure 7-2). Collected over many years, these data have limited accuracy, but they are adequate to define the general shape of the potentiometric surface.

Ground-water movement in the Wasatch Formation in the plant site area is strongly influenced by topography; flow is away from the topographic high in T. 34 N., R. 70 W., sec. 5, about 2 miles southeast of the plant site, toward Willow Creek to the northeast, toward Walker

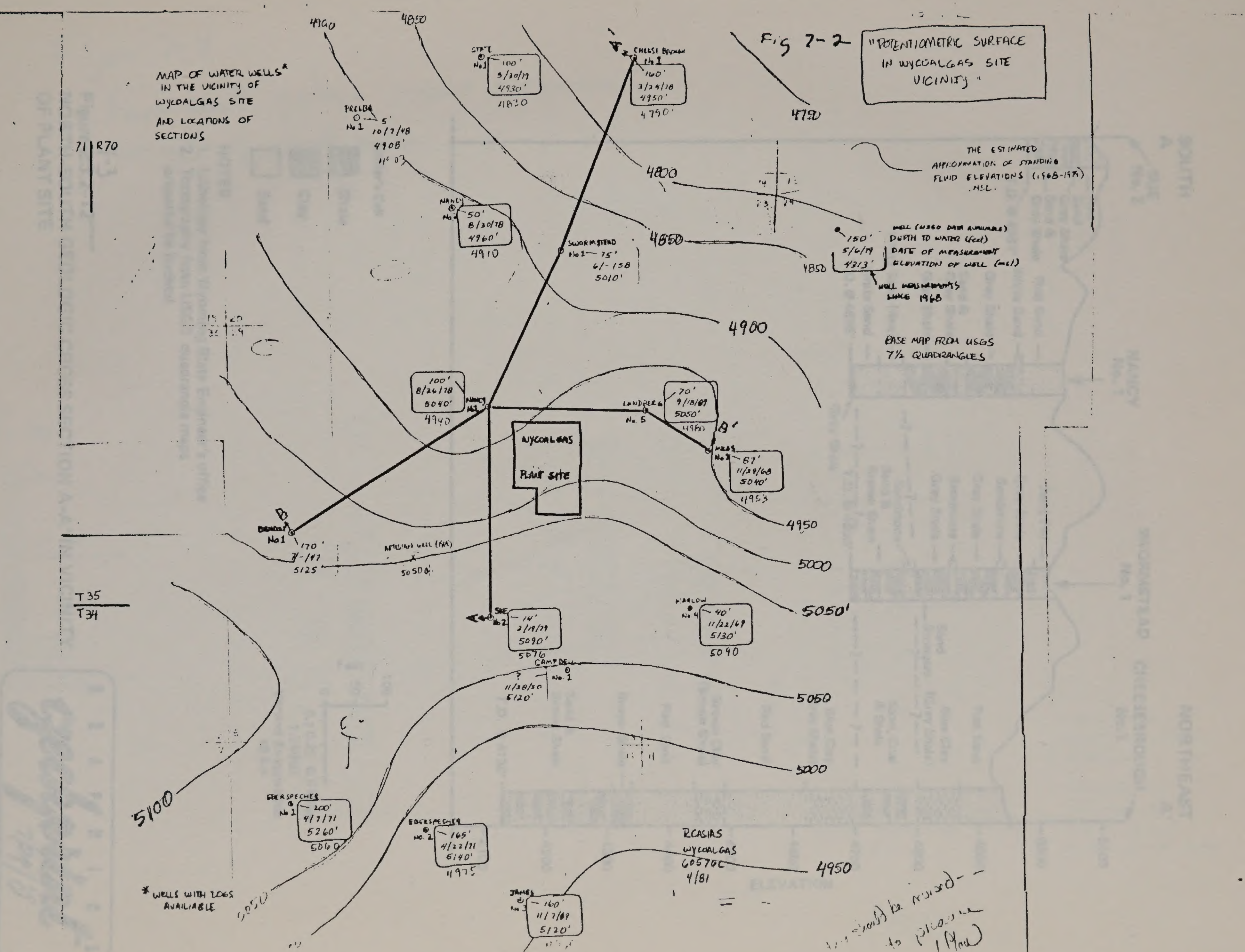
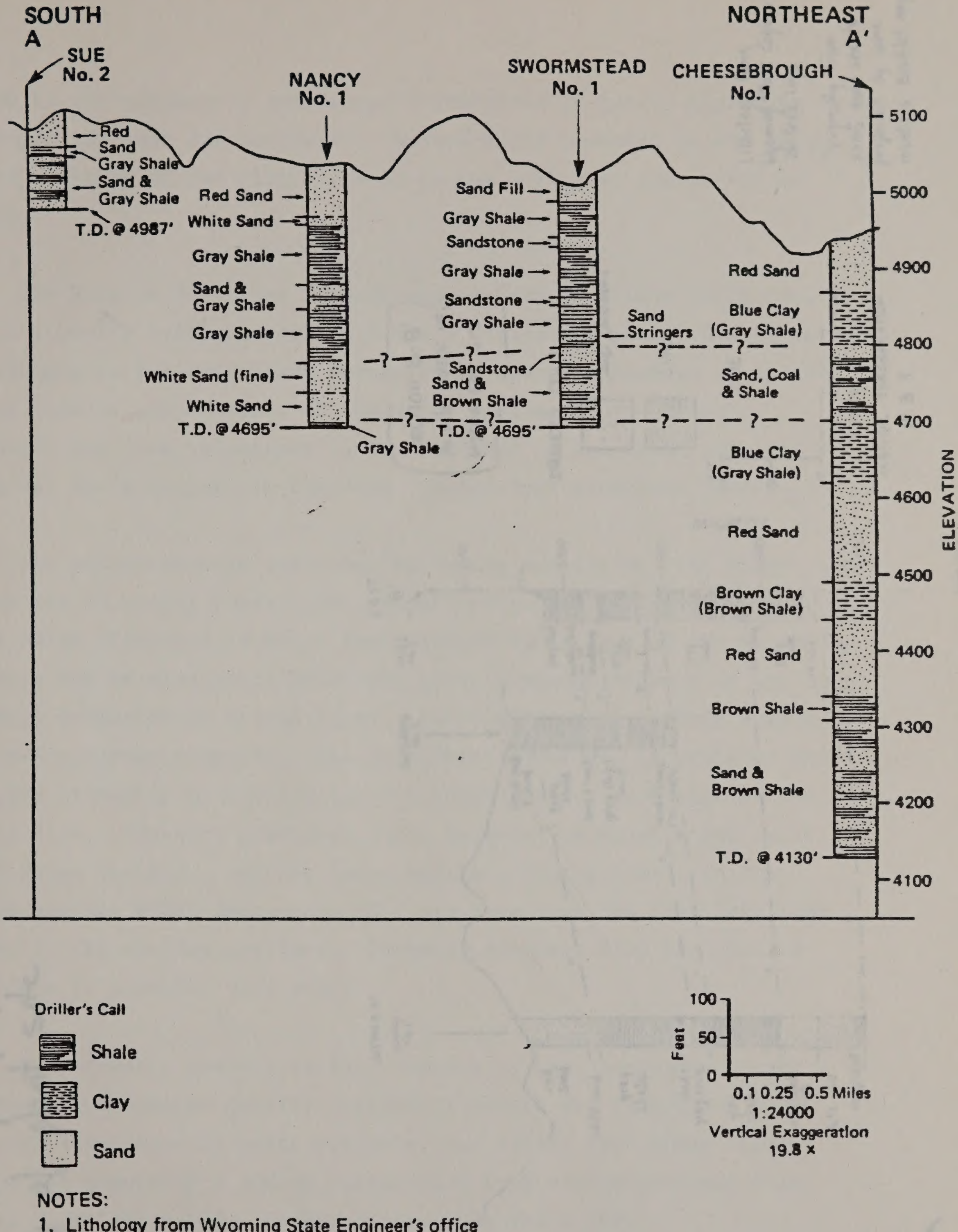


Fig 7-2
"POTENTIOMETRIC SURFACE IN WYCOALGAS SITE VICINITY"
MAP OF WATER WELLS* IN THE VICINITY OF WYCOALGAS SITE AND LOCATIONS OF SECTIONS
T1 R70
THE ESTIMATED APPROXIMATION OF STANDING FLUID ELEVATIONS (1968-1975) MSL.
WELL (USGS DATA AVAILABLE)
DEPTH TO WATER (feet)
DATE OF MEASUREMENT
ELEVATION OF WELL (msl)
WELL MEASUREMENTS SINCE 1968
BASE MAP FROM USGS 7½ QUADRANGLES
WYCOALGAS PLANT SITE
T35
T34
* WELLS WITH LOGS AVAILIABLE
RCASIAS
WYCOALGAS
605706
4/81
4960
4850
4800
4850
4900
4950
5000
5050'
5050
5000
4950
5100
4790



NOTES:

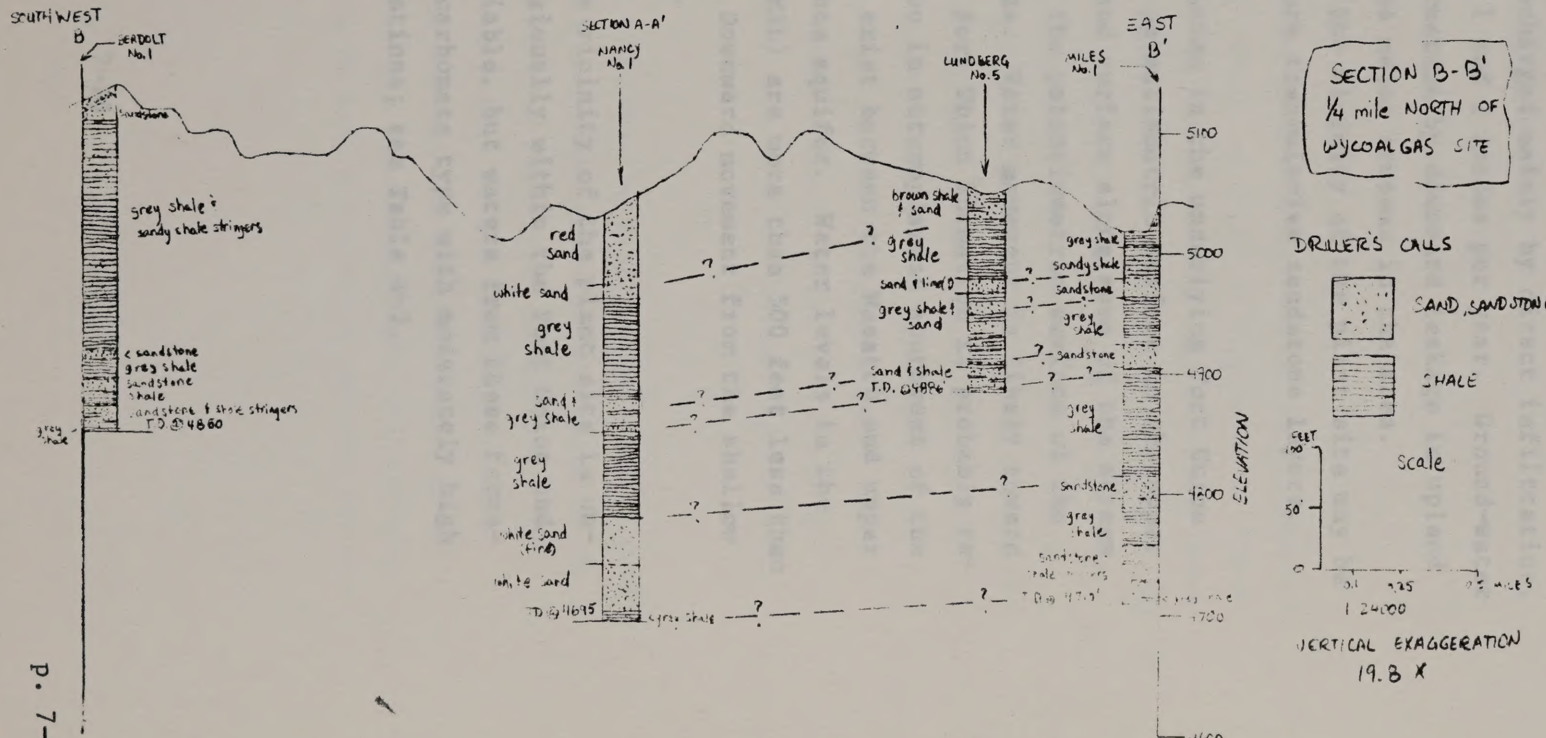
1. Lithology from Wyoming State Engineer's office
2. Topography from USGS quadrangle maps prepared be Bechtel

Figure ~~2.3.2-12~~ 7-3
NORTH-SOUTH GEOLOGIC CROSS SECTION A-A' IN VICINITY OF PLANT SITE

GRAPHICS geoprint 7/29/81

Figure 7-4

East-West geologic cross section in vicinity of plant site



Lithology from Wyoming State Engineer's Driller's Logs

Topography from USGS quad sheets prepared by some insidious Bechtel employee

Re ASIAS
WYCOALGAS

Creek to the southeast, and toward tributaries of Little Lightning Creek to the west and northwest. Ground-water movement in the immediate vicinity of the plant site is to the northeast toward Willow Creek.

The Wasatch Formation is recharged mainly by direct infiltration, which probably averages between 1 and 2 inches per year. Ground-water discharges to the Fort Union Formation by downward leakage in upland areas, and to the channels of the major streams in the area. Ground-water flow velocities in the vicinity of the plant site may be as great as 30 ft/year in the more transmissive sandstone layers.

The potentiometric distribution in the underlying Fort Union Formation is poorly known. The potentiometric surface in the upper Fort Union Formation is above land surface along some of the stream valleys but is apparently below the potentiometric surface of the Wasatch Formation in upland areas. Water movement is likely toward the major stream channels. The Fort Union Formation is probably recharged primarily by infiltration in outcrop areas southwest of the plant site. Downward gradients exist between the Wasatch and upper Fort Union aquifers, and the Lance aquifer. Water levels in the Lance aquifer (4400 feet above MSL) are more than 500 feet less than those in the shallow aquifers. Downward movement from the shallow aquifers is probably very small.

Ground-water quality in the vicinity of the plant site is unknown. Ground-water quality regionally within the Fort Union and Wasatch formations is quite variable, but waters from these formations are generally a sodium bicarbonate type with moderately high total dissolved solids concentrations; see Table 4-2.

Chapter 8
ROCHELLE MINE

8.A SURFACE WATER

8.A.1 Introduction

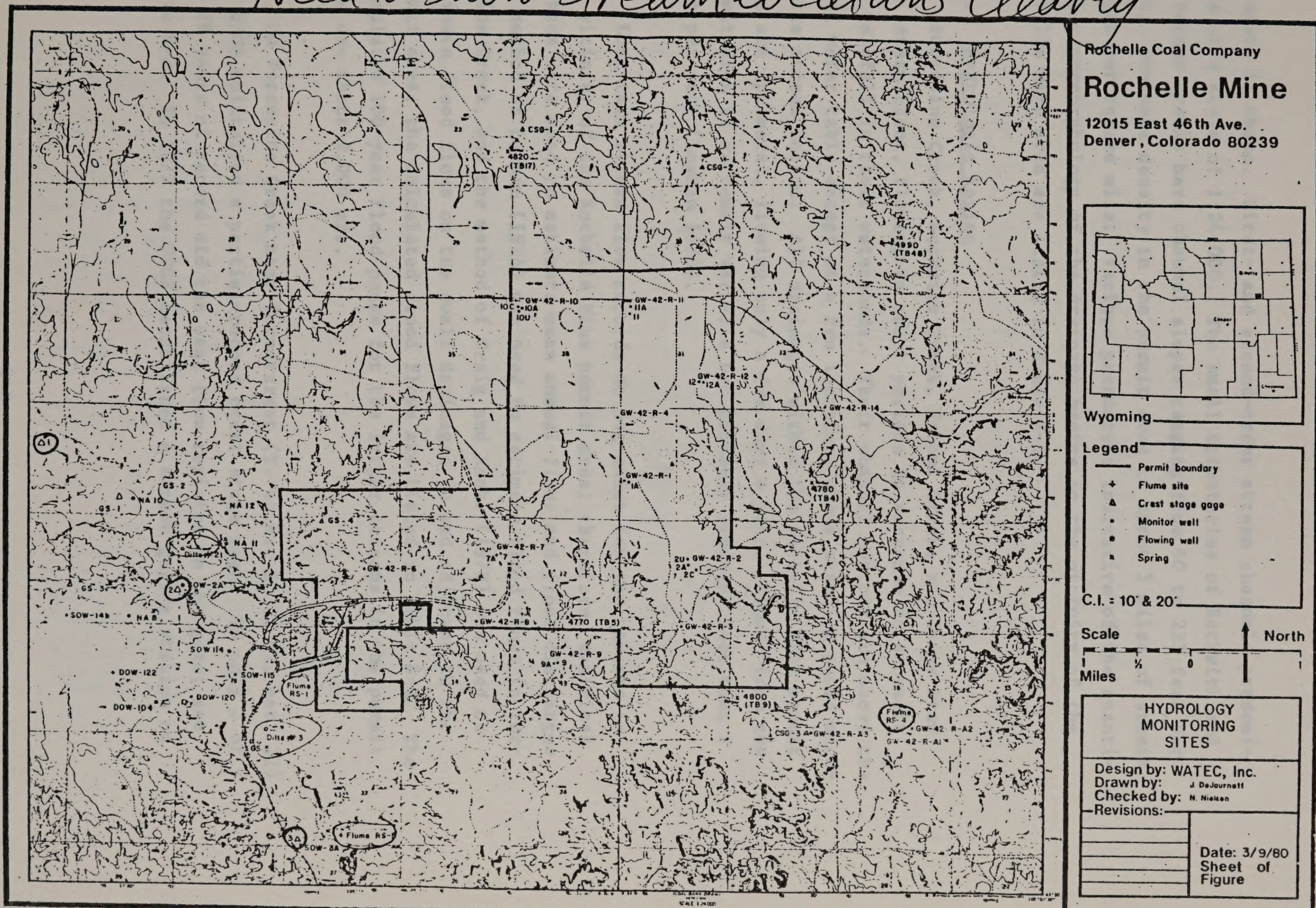
The Rochelle Mine permit area is drained primarily by tributaries of Porcupine Creek and Beckwith Creek, as shown in Figure 8-1. Porcupine Creek lies to the southwest of the mine area, and Beckwith Creek lies east of the mine area. A small portion (0.17 square mile) of the northeastern part of the mine area is drained by School Creek. The northwestern portion of the mine area contains two closed drainage basins encompassing 2.1 square miles. Sunny Draw drains 0.04 square mile in the southeastern part of the mine area. Porcupine Creek, Beckwith Creek, and Sunny Draw are tributaries of Antelope Creek, which is a tributary of the Dry Fork of the Cheyenne River. School Creek is a tributary of Little Thunder Creek, which in turn is a tributary of Black Thunder Creek. All of these streams are in the Cheyenne River drainage basin.

The present morphology of the Rochelle Mine permit area is dominated by the headward erosion of the tributaries of Porcupine Creek and Beckwith Creek into the relatively flat-lying Wasatch and Fort Union formations. The northwestern part of the permit area is a relatively flat plateau, but the eastern and southern edges of the permit area are deeply incised by the headward-cutting tributaries. The drainage basins within the area have a dendritic pattern and are

Figure 8-1 the Rochelle Mine Permit area and vicinity

(hold)

Need to show stream locations clearly



8-2

ROCHELLE

elongate in shape. First- and second-order stream channels predominate at a scale of 1:24,000. The small tributaries of Beckwith and Porcupine creeks have channel slopes ranging from 60 to 233 feet per mile. Drainage density in the permit area is about 3 miles of stream length per square mile. Various parameters indicative of the quantitative geomorphology of the drainage basins in the vicinity of the Rochelle Mine area are listed in Table 8-1.

8.A.2 Hydrologic Regime

Porcupine Creek, Beckwith Creek, School Creek, and Sunny Draw are intermittent, flowing in short periods in response to snowmelt and rainfall in their watersheds. Their channel bottoms are above the local water table except at a few locations where standing pools occupy the stream bottom. All drainages within the Rochelle Mine permit area are ephemeral, flowing only a few days a year. Runoff from the permit area is extremely variable but probably averages less than 1 inch per year (Lowham 1976).

Long-term stream flow records do not exist for the streams in the vicinity of the Rochelle Mine permit area; therefore, empirical methods were used to estimate mean annual flows and flood discharges. The method of Lowham (1976) was used to estimate flood flows in Porcupine Creek, and the method of Craig and Rankl (1978) was used to estimate flood flows on the small drainages in and adjacent to the permit area; the calculated flood flows are listed in Table 8-2. The calculated 100-year flood peaks for the larger streams in the permit area are about 2,000 cfs.

On Porcupine Creek near Turnercrest (T. 42 N., R. 72 W., sec. 11) the USGS maintained a partial-record crest stage gage. In only 3 of the 18 years of record did the peak flow register on the gage; see Table 8-3. In 1977 the USGS established a stream gaging station on

TABLE 8-1

GEOMORPHIC CHARACTERISTICS OF DRAINAGE BASINS IN AND ADJACENT TO THE ROCHELLE COAL MINE

Drainage[a]	Area (mi^2)	Basin Slope[b,] (ft/mile)	Main Channel[c] Slope (ft/mi)	Total Stream[d] Length (mi)	Drainage[e] Density (mi^{-1})	Channel[f] Maintenance (mi^2/mi)	Sinuosity[g]
Beckwith Creek above flume RS-4	6.28	724	69	22.2	3.5	.29	1.3
No. 3 Draw above flume RS-5	7.27	746	58.6	25.2	3.5	.29	1.4
No. 3 Draw in permit area	3.31	451	60	7.8	2.3	.43	1.2
Knapp Draw in permit area	4.06	401	93	14.7	3.6	.28	1.4
No. 2 Draw above flume RS-1	2.39	593	95	6.5	2.7	.37	1.3
Tributary School Creek in permit area	.17	700	166	0.3	1.8	.56	1.1
Beckwith Creek tributaries in permit area							
No. B1	.27	555	214	0.6	2.2	.45	1.1
No. B2	.91	350	134	2.1	2.3	.43	1.2
No. B2	.51	784	213	2.2	4.3	.23	1.3
No. B3	.44	708	233	.8	1.8	.56	1.3
No. B4	.25	400	161	.6	2.4	.42	1.4

[a]The location of the drainages are shown on Figure VII-S2.
[b]basin slope is the average slope in the drainage basin.
[c]main channel slope is the average slope of channel between points 10% and 85% of the distance along the channel from the measuring point to the drainage divide.
[d]drainage density is total stream length in basin divided by basin area.
[e]channel maintenance in the drainage area per mile of stream length
[f]Sinousity is the ratio of stream length to valley length.
[g]?

TABLE 8-2

CALCULATED FLOOD FLOWS FOR THE DRAINAGES IN AND ADJACENT TO THE ROCHELLE COAL MINE

	Area	Mean Annual Flow (cfs)	Peak Flows of Various Recurrence Intervals (cfs)[1]					
			2 year	5 year	10 year	25 year	50 year	100 year
Porcupine Creek at mouth[a]	125	6.7 (1.4)[b]	533	1433	2536	4428	6386	8833
Beckwith Creek at RS-4[b]	6.3		440	1100	1700	2200	3000	4200
Tributary No. B2 at permit boundaries[b]	0.91		210	375	600	800	940	1250
No. 3 Draw at RS-5[b]	7.27		580	1100	1800	2300	3000	4000
No. 3 Draw at Permit boundary[b]	3.31		300	600	900	1400	1700	2000
No. 2 Draw at RS-1	2.39		275	550	800	1300	1700	2000
Knapp Draw at Northern permit boundary	1.77		410	760	1000	1600	2000	2600
Knapp Draw at western permit boundary	4.06		380	770	1300	1800	2000	2800

[a]Porcupine Creek flows calculated using method of Lowham (1976); all other flows calculated using method of Craig and Rankl (1978).

[b]Based on relationship between unit runoff and drainage area developed by Hadley and Schumm (1961) for the upper Cheyenne River basin.

TABLE 8-3

ANNUAL PEAK FLOWS IN PORCUPINE CREEK NEAR TURNERCREST[1]

Date of Annual Peak	Annual Peak Discharge (cfs)
6-29-59	a
1960	b
7-8-61	758
6-15-62	1230
2-1-63	a
1964	b
1965	b
1966	b
1967	b
1968	b
1969	b
7-27-70	440
1971	c
1972	c
1973	c
1974	c
1975	c
1976	c

a - No estimate made
b - Peak stage did not reach bottom of gage
c - No evidence of flow

[1] The USGS gaging station near Turnercrest (No. 06363700) was located at bridge on State Highway 59 (T. 42 N. R. 72 W. sec. 11ac) about 15 miles northwest of the Rochelle Mine permit area. The drainage area above the gage is 31.5 sq mi.

a perennial reach of Antelope Creek approximately one-half mile downstream of the mouth of Porcupine Creek. The average monthly discharges are listed in Table 8-4.

During the past 2 years the Rochelle Coal Company and the North Antelope Coal Company have established a number of continuous gaging stations and crest gages on the various tributaries that drain the respective mine sites; locations of these stations are shown in Figure 8-1. The first complete year of gaging was water year 1980, a dry year in which annual precipitation was only 11.9 inches. Runoff from the gaged watersheds ranged between 0.02 and 0.24 inch; see Table 8-5.

8.A.3 Sediment Yields

Annual sediment yields from the permit area (excluding the 2.1 sq mi of internally drained basins), with primarily Wasatch Formation outcrops, are probably in the range of 0.1 to 1.1 acre-feet per square mile (Hadley and Schumm 1961); therefore, total sediment yield from the permit area is probably between 0.8 and 9 acre-feet per year. Sixty percent of the sediment is derived from sheet and sill erosion and 40 percent from channel erosion (Rochelle Coal Company 1981). An erosion rate of 0.1 ac-ft/sq mi/yr translates into an average sediment concentration of 28,000 mg/l, assuming an average annual runoff of 0.7 inch per year. Recorded sediment concentrations in the drainage basins have ranged from 57 to 64,291 mg/l; see Table 8-6. The information required to calculate total sediment transport during a runoff event was not available.

Most reaches of stream in the vicinity of the mine area are incised. The stream incising now seen in the area apparently began in the late 1800s as a response to overgrazing and climatic change (Goodwin 1976). Four short reaches in the area are presently aggrading; all occur immediately upstream of stock watering ponds. Many

TABLE 8-4

AVERAGE MONTHLY FLOWS IN ANTELOPE CREEK DOWNSTREAM OF MOUTH OF PORCUPINE CREEK[a]

	Flows (cfs)		
	1978	1979	1980
October	0.17	0.15	0.21
November	0.18	0.17	.35
December	0.17	0.35	.95
January	0.15	0.25	3.3
February	0.17	0.65	3.9
March	20	17	11
April	2.0	22	8.0
May	222	8.2	4.6
June	14	11	5.0
July	71	14	.26
August	7.8	10	.14
September	0.65	0.64	0.0
Average annual flow (cfs)	28.7	7.1	3.14
Average annual runoff (inches)	0.41	0.10	0.04

[a]Data are from USGS gaging station, Antelope Creek near Teckla, Wyoming (No. 06364700) which is located in T. 41 N., R. 70 W. sec. 35ac about 0.4 mile downstream from Porcupine Creek.

TABLE 8-5

STREAM FLOW RECORDS FOR WATER YEAR 1980

	Total Monthly Precipitation[a] (inches)	Total Monthly Flows (acre-feet)		
		RS-1	RS-5	RS-4
October	.59	--	--	--
November	.69	--	--	--
December	.00	--	--	--
January	.93	--[b]	--[b]	--[b]
February	.85	1.8	--	21
March	1.39	--	--	--
April	.85	--	--	--
May	2.73	0.7	4.7	42.0
June	.00	0.06	2.7	5.6
July	1.53	--	--	5.0
August	2.82	0.06	28.0	8.5
September	.23	--	--	
Total	12.6	2.62	35.4	82.0
Average annual runoff (inches)		0.02	0.09	0.25

[a]Precipitation recorded at NOAA Weather Station, Dull Center, Wyoming, which is located about 15 miles southeast of Rochelle Mine.
[b]Recorders not operating January 15 to February 10.

TABLE 8-6
SURFACE WATER QUALITY IN THE VICINITY
OF THE ROCHELLE COAL MINE PERMIT AREA

	Porcupine Creek[a] (July 9, 1980)			Beckwith Creek[a] (February 1980)		Antelope Creek[b] near Teckla		
	Site 1	Site 2	Site 3	RS-4	CGS-3	Average	Min	Max
Conductivity	1,386	482	359	638	773	2,150	435	2,650
Total dissolved solids	1,211	342	252	742	892	1,670	292	2,120
Total suspended solids	1	8	15	57	48	128	5	1,130
pH	7.3	7.0	7.7	7.4	7.8	--	7.9	8.3
Total alkalinity	173	60	144	86	117	310	56	440
Total hardness	--	--	--	396	566	850	--	1,200
Calcium	185	42	24	83	143	230	33	300
Magnesium	56	19	26	41	45	31	13	110
Sodium	41	12	9	43	22	190	28	280
Potassium	25	13	13	14	17	14	5	21
Iron (dissolved)	.07	.34	.24	.08	.08	.05	0.0	0.34
Manganese (dissolved)	.02	.03	.04	.2	.2	.17	.003	.57
Bicarbonate	173	60	144	136	184	370	68	540
Sulfate	728	173	47	388	458	940	150	1,200
Chloride	3	3	3	5	4	16	4	31
Fluoride	.08	.56	.54	.37	.40	.54	.2	1.1
Boron	.87	.06	.05	.46	.80	.18	.05	.54
Cadmium	.01	.01	.01	.002	0.0	--	--	--
Selenium	.001	.001	.001	.001	.001	--	--	--

Sources: [a]Rochelle Coal Company 1981.
[b]EPA STORET Retrieval 1981.

reaches appear to be in equilibrium, stabilized by channel vegetation consisting mostly of native grasses.

8.A.4 Water Quality

Porcupine Creek. Water quality samples have been taken periodically since March 1978 from three locations in Porcupine Creek (numbered 1,2, and 3 in Figure 8-1). On only one occasion during this 2-year period was a suite of samples taken from all three sites when there was measurable flow in the creek. The quality of the water in Porcupine Creek on this date (July 9, 1979) improved in a downstream direction; see Table 8-6. The total dissolved solids concentrations change from 1,211 mg/l at the upstream site, to 342 mg/l at site no. 2, to 252 mg/l at the downstream site. The water type changed from a calcium sodium sulfate type at the upstream site to a calcium bicarbonate type at the downstream site. The water at the upstream site was suitable for stock watering and marginally suitable for irrigation; at the downstream site it was suitable for all domestic and stock uses.

Beckwith Creek. Water quality samples have been collected only once in the Beckwith Creek drainage because flow has been infrequent since the monitoring program began in June 1979. Samples were taken on February 11, 1980 during snowmelt at sampling site RS-4, located on the main channel of Beckwith Creek, and at monitoring site CSG-3, located on a tributary of Beckwith Creek (Table 8-6). The sampled waters were a calcium sulfate type of medium salinity.

Antelope Creek. Downstream from the mine, Antelope Creek is intersected by Porcupine Creek. Since 1977 the USGS has maintained a gaging station and collected water samples for chemical analysis from a point 0.4 mile downstream from the confluence with Porcupine Creek. The results of selected water quality analyses for this station are

listed in Table 8-6. This water could be classified as a mixed cation sulfate type of medium salinity. The predominant cations are calcium, sodium, and magnesium, in that order. Water quality at this point is adequate for stock watering but in most cases would require careful management practices if applied to agricultural lands. Trace element content is low.

Cheyenne River

Further downstream, Antelope Creek drains into the Cheyenne River, which collects drainage primarily from the Dry Fork of the Cheyenne River. The USGS has maintained a gaging station and collected water samples on the Cheyenne River 1.2 miles downstream from the confluence of Antelope Creek and Dry Fork Cheyenne River since 1976. A summary of available water quality parameters for selected constituents is listed in Table 8-7. This downstream water usually contains more dissolved and suspended constituents than the water of Antelope Creek. The water could be characterized as a mixed cation sulfate type. The concentrations of dissolved metals are low.

School Creek

A small portion of the mine site is drained by School Creek, a tributary of Little Thunder Creek. A limited water quality survey was made during July through November, 1975. Four water samples were obtained from standing water in School Creek, and in Little Thunder Creek upstream and downstream of School Creek. The results of these monitoring efforts are listed in Table 8-8.

The USGS maintains a surface water gaging station 2.7 miles upstream from the confluence of Little Thunder Creek and Black Thunder Creek; water quality samples are also obtained and analyzed. During low-flow periods, the water could be characterized as a sodium sulfate

TABLE 8-7

WATER QUALITY OF THE CHEYENNE RIVER
(Near Dull Center - Lat. 43° 25' 45", Long. 105° 02' 43")

Parameter[a]	Concentration		
	Average	Minimum	Maximum
General			
Water temperature, °C	14	0.0	31.0
pH, units	-	7.3	8.7
Conductivity, μmhos/cm 25°C	2,690	910	3,700
Total dissolved solids (sum)	2,100	613	3,810
Total suspended solids	1,900	26	21,500
Total Alkalinity (as $CaCO_3$)	260	98	527
Total hardness (as $CaCO_3$)	1,020	320	1,800
Dissolved oxygen	9.3	6.1	12.0
Common Ions			
Calcium	240	80	400
Magnesium	100	13	200
Sodium	270	74	500
Potassium	16	1.7	28
Iron, dissolved	0.066	0	0.540
Manganese, dissolved	0.35	0.023	1.1
Biocarbonate	316	120	643
Carbonate	6	0	270
Sulfate	1,300	330	2,300
Chloride	23	5	42
Fluoride	0.5	0	0.8
Boron	0.12	0.06	0.27

Source: EPA 1981.
[a] All constituents in mg/l unless otherwise indicated.

TABLE 8-8

WATER QUALITY OF LITTLE THUNDER CREEK AND SCHOOL CREEK (STOCK POND)

	Concentrations								
	Upper Little Thunder Creek (Lat. 43° 40'; Long. 105° 17')			School Creek (Lat. 43° 90'; Long. 105° 10')			Lower Little Thunder Creek (Lat. 43° 40'; Long. 105° 11')		
Parameter	Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum
Water temperature (°C)	15.5	2.2	29.4	15.1	2.2	24.4	15.7	2.2	22.2
pH (units)	-	8.8	10.50	9.2	9.0	9.6	9.3	8.7	10.1
Conductivity (mhos/cm at 25°C)	1,950	800	2,300	1,500	800	2,200	3,450	800	6,000
Total alkalinity (as $CaCO_3$)(mg/l)	270	130	450	190	150	250	290	260	320
Total hardness (as $CaCo_3$)(mg/l)	580	270	820	730	570	1000	1100	260	2120
Turbidity (NTU)	21	10	30	43	20	60	45	10	75
Suspended sediment (mg/l)	27.5	1.5	45.2	51.3	16.3	101.2	60	17	120
Stream flow (cfs)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Source: EPA STORET retrieval 2/81.

type. During high-flow periods, calcium and magnesium may predominate. Generally an inverse relationship exists between TDS and flow. The concentrations of dissolved trace elements are low.

8.B GROUND WATER

8.B.1 Introduction

The major water-bearing strata in the vicinity of the proposed Rochelle coal mine are the alluvial deposits in the creek valleys; the Roland coal seam; sandstone beds in the Wasatch Formation and the Fort Union Formation; the Lance and Fox Hills formations; the Inyan Kara Group; and the Madison Group. The regional hydrogeologic setting of Campbell and Converse counties, Wyoming is described in the Final Environmental Impact Statement for Proposed Development of Coal Resources in Eastern Powder River Wyoming (BLM 1979).

All domestic and stock wells in the vicinity of the proposed mine sites obtain water from the alluvial deposits, the Roland coal seam, and the sandstone beds in the Wasatch and the upper member of the Fort Union Formation. Water yields from these strata are typically in the range of 1 to 50 gpm. Even though larger yields could be obtained from deeper aquifers, the cost of obtaining water from these aquifers would be very high. The proposed mine would affect only aquifers in the alluvial deposits and in the Fort Union Formation. Since there would be no impact on deeper aquifers, these aquifers are not discussed further.

The near-surface aquifers on the Rochelle coal mine site have been studied by the Rochelle Coal Mine Company since March 1969 (Rochelle Coal 1981). The near-surface aquifers at the adjacent North Antelope and Antelope mines were studied from 1977 to 1980 and are described in the North Antelope Mine Permit Application

(North Antelope Coal Company 1981) and in the Antelope Mine Permit Application (Antelope Coal Company 1980). The shallow aquifers in the vicinity of the Rochelle Mine are also described in the USFS - SEAM (1979) study. Detailed studies of the Wasatch and Roland aquifers approximately 10 miles north of the Rochelle Mine in the vicinity of the Black Thunder and Jack's Ranch mines have been conducted by the University of Wyoming since 1973 (Eisen 1981).

8.B.2 Aquifer Units

Alluvial Deposits. Mappable alluvial deposits exist in the valleys of the West Fork of Beckwith Creek and in the valley of Porcupine Creek adjacent to the Rochelle Mine permit area. The alluvial deposits are lithologically variable, containing lenticular deposits of fine sand, silt, clay, and clinker gravels. The dominant particle size by visual inspection is very coarse sand to medium gravel. The deposits vary in thickness; they are reported by Rochelle Coal Company (1981) to be as deep as 40 feet in the Porcupine Creek valley and 27 feet deep in Beckwith Creek. The transmissivity of the alluvial deposits has been estimated to range from 21 to 400 sq ft/day; see Table 8-9.

Wasatch Formation. The Wasatch Formation, which overlies the Roland coal, consists of highly lenticular beds of fine to coarse grained sandstone with interbeds of coal and shale. It is about 80 percent clay-shale and 20 percent lenticular sandstone and ranges in thickness from 0 to 250 feet. The surface stratum over most of the Rochelle Mine permit area is part of the Wasatch Formation. The transmissivity of selected intervals of the Wasatch Formation in the Rochelle Mine permit area has been estimated to range between 0.2 and 2.5 square feet per day. (Rochelle Coal Co. 1981).

TABLE 8-9

HYDROGEOLOGIC PROPERTIES OF AQUIFER UNITS IN
THE VICINITY OF THE ROCHELLE COAL MINE

Aquifer Unit	Thickness (feet)	Transmissivity (sq ft/day)	Storage Coefficient	Comments
Porcupine Creek Alluvium	0 - 40	21 - 400	--	
Beckwith Creek Alluvium	0 - 27	21 - 400	--	
Roland Coal	30 - 80	0.2 - 360	0.002 - 0.003	
Roland Clinker	0 - 240	?	--	
Wasatch Formation	0 - 250	0.2 - 150	--	
Fort Union Formation below Roland Coal	2,500	0.2 - 2.0	--	only upper 100 feet of unit tested

Source: Rochelle Coal Company 1981.

Roland Coal. The Roland coal deposits at the Rochelle Mine site range from about 30 to 80 feet thick. In some areas it is a single coal seam, while in others it is parted by thin interbedded shales. The southern and eastern extent of the Roland coal is defined by thick clinker beds that formed when the Roland coal seam burned.

The transmissivity of the Roland coal in the mine site area was estimated to range between 0.2 and 1 sq ft/day (Rochelle Coal Co. 1981). The transmissivity of the Roland coal at the adjacent North Antelope Mine was estimated to range between 13 and 123 sq ft/day (Table 8-9). The regional transmissivity of the coal seam is mainly the result of interconnected fractures in the coal. The transmissivity calculated from an individual well will be mainly a function of the number of fractures intercepted by the well. The actual regional transmissivity is likely to be higher than the low estimates and somewhat lower than the high estimates.

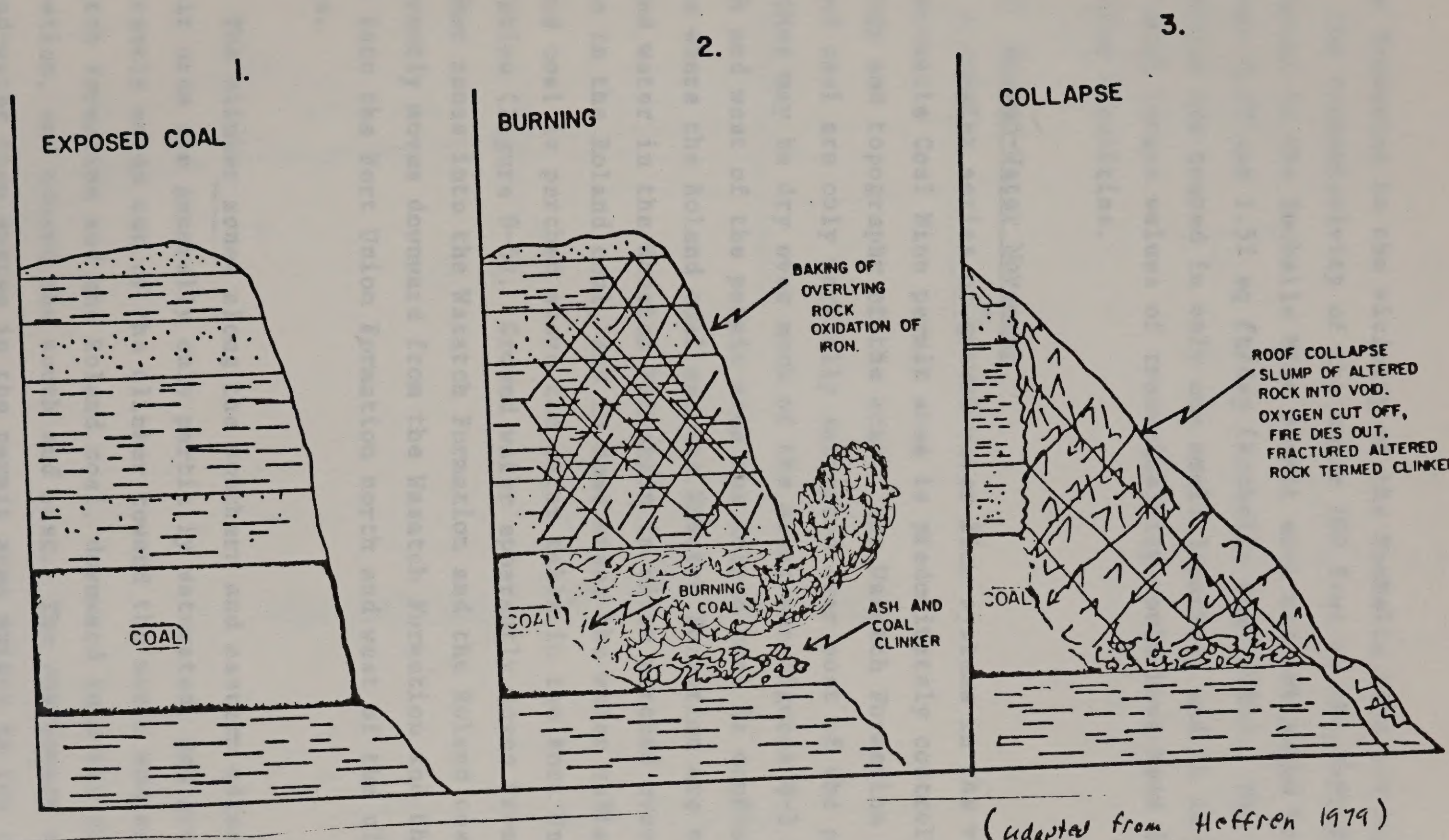
Roland Clinker. Clinker deposits are found adjacent to the Roland coal subcrop northeast, east, and south of the Rochelle Mine area. The clinkers formed when the Roland coal seam burned, probably in the Pleistocene epoch (Heffren 1979); see Figure 8-2. The burning of the coal baked and fused the sandstone, siltstone, and shales of the overlying Wasatch Formation. This material subsequently collapsed into the void created by the burning of the coal. Clinker beds are generally two to four times thicker than the coal seams that burned (Matsen and Blumer 1973). The transmissivity of clinker is generally very high because it is highly fractured and very porous.

Fort Union Formation. The Fort Union Formation in the vicinity of the Rochelle Mine area is approximately 2,500 feet thick and consists of approximately 10 major coal beds separated by shales, clays, and discontinuous sandstone lenses. Only the upper 100 feet of the Fort

Fig 8 Bo

Figure 8-2

hold



(adapted from Heffren 1979)

Figure ~~5.21~~ 8-2. The formation of clinker.

Union Formation in the vicinity of the Rochelle Mine has been described. The transmissivity of the upper 100 feet of the Fort Union Formation in the Rochelle Mine permit area was estimated to range between 0.20 and 1.57 sq ft/day (Rochelle Coal 1981). The Fort Union Formation was tested in only one small location, and it is very likely that much larger values of transmissivity would have been determined in other localities.

8.B.3 Ground-Water Movement

A complex series of ground-water flow systems in the vicinity of the Rochelle Coal Mine permit area is predominately controlled by the geology and topography of the area. The Wasatch Formation and the Roland coal are only partially saturated over most of the permit area, and they may be dry over much of the area; see Figures 8-3 and 8-4). North and west of the permit area the Roland coal is confined. In areas where the Roland coal and the Wasatch Formation are not dry, ground water in the Wasatch Formation is often perched over a water table in the Roland coal, and in some areas the water table in the Roland coal is perched above the water table in the Fort Union Formation (Figure 8-5). Ground water apparently moves from the clinker zones into the Wasatch Formation and the Roland coal, and apparently moves downward from the Wasatch Formation and the Roland coal into the Fort Union Formation north and west of the clinker zones.

The clinker zones along the southern and eastern edges of the permit area are generally only partially saturated, and ground water apparently moves out of the clinker toward the north and east into the Wasatch Formation and the Roland coal, downward into the Fort Union Formation, and toward the south and east. The shallowest continuous ground-water flow system in the permit area exists in the upper parts of the Fort Union Formation. The general direction of ground-water

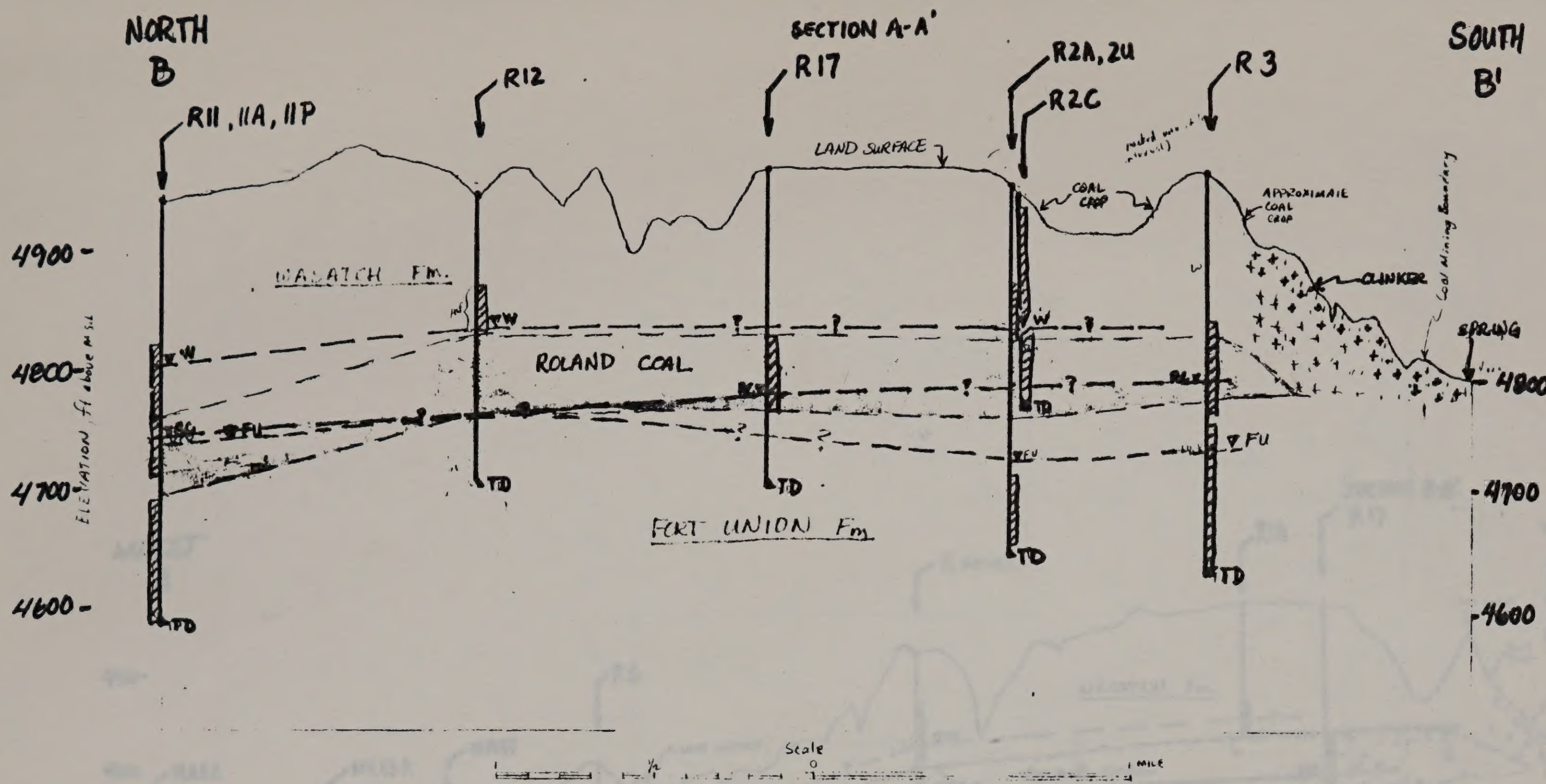
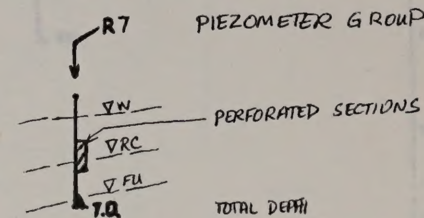


Plate __

Fig 8-3 Hydrogeologic Cross-Section B-B', [illegible]



LEGEND

Limits of Roland Coal

? W — Potentiometric Surface for Wasatch Formation (QUERIED WHERE INFERRED)

? RC — Potentiometric Surface for Roland Coal (QUERIED WHERE INFERED)

? FU — Potentiometric Surface for Fort Union Formation (QUERIED WHERE INFERED)

Clinker

W — Water level for Wasatch Formation

RC — Water level for Roland Coal

FU — Water level for Fort Union Formation

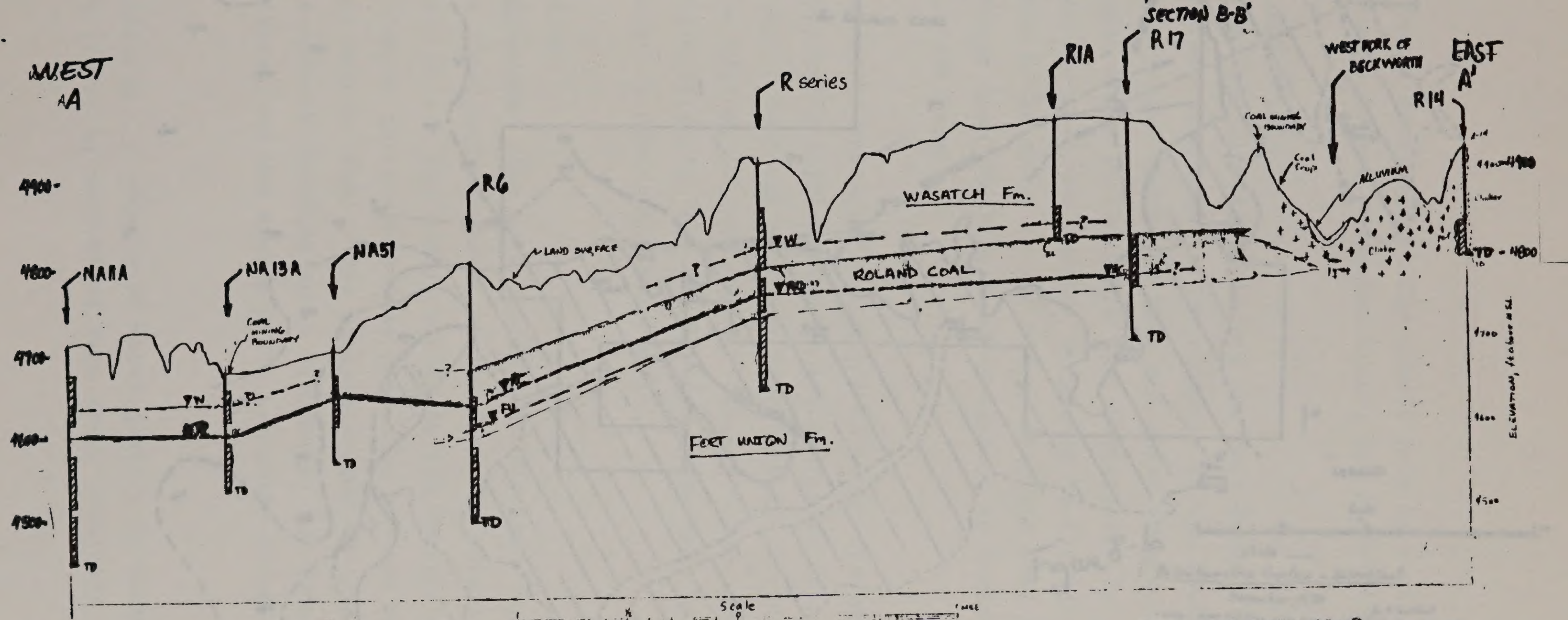


Fig 8-4

Plate ___ Hydrogeologic Cross Section A-A', Rochelle Mine

LEGEND

"Limits of Roland Coal"

?— W — Potentiometric Surface for Wasatch Formation

?— RC — Potentiometric Surface for Roland Coal

?— FU — Potentiometric Surface for Fort Union Formation

Clinker (Potentiometric surface queried where Infered)

R7 PIEZOMETER GROUP
(NA - series wells do not have geologic log)

TED SECTIONS

TOTAL DEPTH

W — Water level for Wasatch Formation

RC — Water level for Roland Coal

FU — Water level for Fort Union Formation

hold

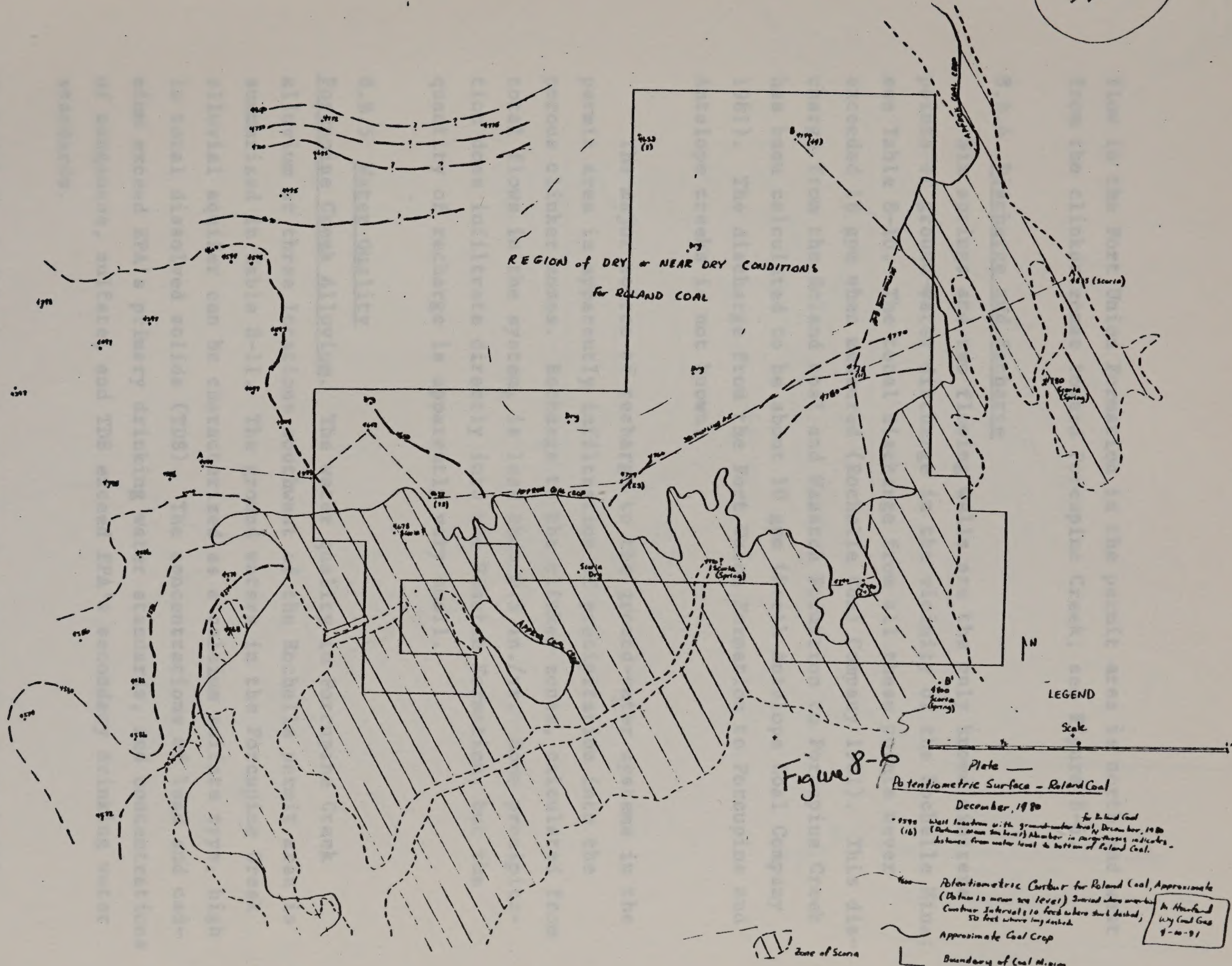


Figure 8-6

flow in the Fort Union Formation in the permit area is north and west from the clinker zones toward Porcupine Creek; see Figure 8-6.

8.B.4 Discharge and Recharge

Six springs and two flowing wells are the only known discrete points of ground-water discharge in the vicinity of the Rochelle Mine; see Table 8-10. The total discharge from all these points never exceeded 18 gpm when measured (Rochelle Coal Company 1981). This discharge from the Roland coal and Wasatch Formation to Porcupine Creek has been calculated to be about 10 gpm (North Antelope Coal Company 1981). The discharge from the Fort Union Formation to Porcupine and Antelope creeks is not known.

The major source of recharge to the ground-water systems in the permit area is apparently infiltration of precipitation into the porous clinker zones. Recharge to the clinker zones, calculated from total flows in the system, is less than 0.5 in./yr. Some precipitation does infiltrate directly into the Wasatch Formation, but the quantity of recharge is apparently very small.

8.B.5 Water Quality

Porcupine Creek Alluvium. The water quality in Porcupine Creek alluvium at three locations southwest of the Rochelle permit area is summarized in Table 8-11. The ground waters in the Porcupine Creek alluvial aquifer can be characterized as a calcium sulfate type, high in total dissolved solids (TDS). The concentrations of lead and cadmium exceed EPA's primary drinking water standards, and concentrations of manganese, sulfate, and TDS exceed EPA's secondary drinking water standards.

Beckwith Creek Alluvium. A summary of water quality in Beckwith Creek alluvial aquifers, as determined from three locations, is listed

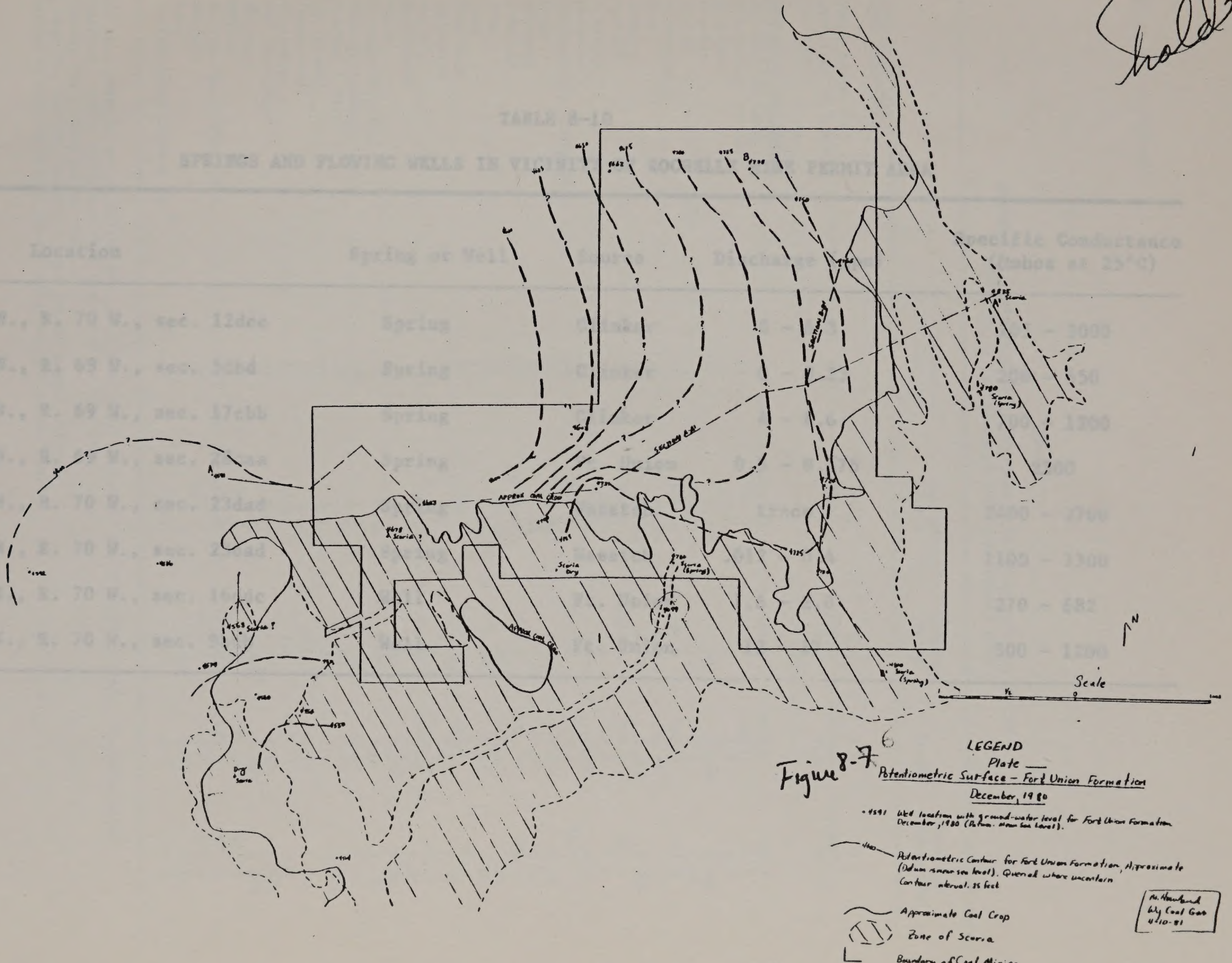

Scale
LEGEND
Plate ___
Potentiometric Surface – Fort Union Formation
December, 1980
Well location with ground-water level for Fort Union Formation December, 1980 (Datum: Mean Sea Level).
Potentiometric Contour for Fort Union Formation, Approximate (Datum mean sea level). Queried where uncertain. Contour interval: 25 feet
Approximate Coal Crop
Zone of Scoria
Boundary of Coal Mining
Scoria (Spring)
Scoria Dry
Approx. Coal Crop
Section B-B'
Section A-A'

Figure 8-7

TABLE 8-10

SPRINGS AND FLOWING WELLS IN VICINITY OF ROCHELLE MINE PERMIT AREA

Location	Spring or Well	Source	Discharge (gpm)	Specific Conductance (µmhos at 25°C)
T. 41 N., R. 70 W., sec. 12dcc	Spring	Clinker	0 - 6.3	105 - 3000
T. 41 N., R. 69 W., sec. 5dbd	Spring	Clinker	0 - 0.25	200 - 650
T. 41 N., R. 69 W., sec. 17cbb	Spring	Clinker	4 - 8.6	700 - 1200
T. 42 N., R. 69 W., sec. 28caa	Spring	Ft. Union	0.3 - 0.375	2300
T. 42 N., R. 70 W., sec. 23dad	Spring	Wasatch	trace	2400 - 2700
T. 42 N., R. 70 W., sec. 23dad	Spring	Wasatch	.012 - 0.4	1100 - 1300
T. 41 N., R. 70 W., sec. 16ddc	Well	Ft. Union	1.6 - 2.0	270 - 682
T. 41 N., R. 70 W., sec. 9bcb	Well	Ft. Union	12 - 17	300 - 1200

TABLE 8-11

SUMMARY OF WATER QUALITY IN THE PORCUPINE CREEK ALLUVIUM IN THE VICINITY OF THE ROCHELLE COAL MINE PERMIT AREA

	Number of Samples	Maximum Value	Minimum Value	Mean	Standard Deviation
FIELD PARAMETERS					
Temperature (°C)	10	12.0	7.5	9.5	1.4
Conductivity (µmho/cm at 25°)	10	4,851.0	1,350.0	3,176.8	938.7
ph (units)	10	7.5	6.7	7.0	$10^{-7.2}$
LABORATORY PARAMETERS[a]					
Acidity (As $CaCO_3$)[b]	10	-421.0	-129.0	-373.1	-88.3
Alkalinity (As $CaCO_3$)	10	506.0	323.0	440.3	43.5
Aluminum	11	18.0	0.4	5.2	5.9
Arsenic	11	0.025	.001[e]	0.008	0.008
Barium	3	0.2	0.2	0.2	0.00
Bicarbonate	10	506.0	323.0	440.3	43.5
Boron	11	0.42	0.051[e]	0.20	0.12
Cadmium	11	0.024	.011[e]	0.014	0.004
Calcium	11	450.0	122.0	373.1	104.1
Chloride	10	24.0	5.0	14.6	6.1
Chromium	11	0.06	0.03	0.04	0.01
Conductivity (µmho/cm at 25°C)	10	4330.0	1020.0	2275.3	1020.7
Copper	11	0.15	0.04	0.07	0.03
Fluoride	10	1.00	0.55	0.67	0.12
Hardness	11	1898.0	549.0	1502.5	366.7
Iron	11	0.26	.05[e]	0.07	0.06
Lead	11	0.24	0.04	0.10	0.07
Magnesium	11	174.0	56.0	138.5	31.5
Manganese	11	1.87	0.02	0.54	0.57
Mercury	11	0.58	.02[e]	0.14	0.17
Molybdenum	7	0.2	.1[e]	0.14	0.05
Nickel	11	0.07	.05[e]	0.06	0.00
Nitrogen-Kjeldahl	10	6.54	0.20	1.47	1.75
Nitrogen-Ammonia	10	1.23	.10[e]	0.24	0.33
Nitrate + Nitrite[c]	10	1.78	0.03	0.41	0.49
pH (Units)	10	8.1	7.4	7.6	$10^{-7.9}$
Phosphorous	10	4.23	0.01	0.54	1.24
Potassium	11	18.0	5.0	11.3	4.3
SAR (Unitless)	11	6.17	2.73	4.27	1.47
Selenium	11	0.01	.001[e]	0.002	0.002
Sodium	11	586.0	174.0	384.7	168.3
Solids, Total Dissolved	9	4164.0	1130.0	2889.4	922.5
Sulfate	10	2553.0	610.0	1372.7	676.3
Zinc	11	0.53	0.04	0.13	0.13
Cation-Anion Balance (%)[d]	9	24.7	7.7	8.5	11.9

[a] All measurements are in milligrams per liter (mg/l) dissolved constituents unless otherwise noted.
[b] Negative acidity indicates that the water is alkaline.
[c] Nitrate ion concentration only.
[d] A negative balance indicates that anions exceed cations.
[e] Indicates concentrations below analytical detection limits.

in Table 8-12. The ground waters are a calcium sulfate type, moderately high in TDS. The water meets all EPA primary drinking water standards, but the secondary standards for iron, manganese, sulfate, and TDS are exceeded in some samples.

Wasatch Formation. Ground waters in the Wasatch Formation at the three sampled locations are a sodium bicarbonate type (Table 8-13). The waters exceed EPA's primary drinking water standards for aresenic, barium, chromium, and lead, and the secondary drinking water standards for manganese, sulfate, TDS, and iron. These ground waters are suitable for livestock and irrigation only of salt-tolerant plants.

Roland Formation. No ground-water samples were taken from the Roland coal seam within the permit area because of the limited saturation thickness. Ground-water quality in the Roland coal in the adjacent North Antelope permit area is very similar to that in the Wasatch Formation on the Rochelle permit area; see Table 8-13.

Fort Union Formtion. Water in the upper part of the Fort Union Formation is a sodium sulfate bicarbonate type, with TDS ranging between 900 and 3,000 mg/l (Table 8-13). These ground waters sometimes exceed EPA's primary drinking standards for manganese, sulfate, iron, and TDS. The waters are unsuitable for irrigation because of their high salinity and medium to high sodium hazard, but they are suitable for livestock.

8.C HYDROLOGIC IMPACTS DURING MINE OPERATION

8.C.1 Ground-Water Inflow to Rochelle Mine

The magnitude of ground-water inflows to the Rochelle Mine were calculated with analytical solutions that approximate the hydrogeologic conditions to be produced by mining. Calculations of ground-

TABLE 8-12

SUMMARY OF WATER QUALITY IN THE ALLUVIUM OF BECKWITH CREEK AND TRIBUTARIES IN VICINITY OF ROCHELLE COAL MINE PERMIT AREA

	Well A1			Well A2			Well A3		
	No. of Samples	Mean	Std. Dev.	No. of Samples	Mean	Std. Dev.	No. of Samples	Mean	Std. Dev.
FIELD PARAMETERS[a]									
Conductivity (µmhos/cm at 25°C	4	1299.43	16.56	4	383.5	62.85	4	1219.55	575.82
pH (units)	4	6.8	NA	4	6.72	NA	4	6.77	NA
Water Temperature (C)	4	11.38	1.9	4	13.2	2.66	4	11.88	2.12
LABORATORY PARAMETERS[a]									
Acidity (as $CaCO_3$)[b]	3	-153	-24.02	3	-57.67	-45.37	3	-152.67	-19.5
Alkalinity (as $CaCO_3$)	4	176.5	16.03	4	83.75	42.79	4	172.5	9.47
Aluminum	4	.35	.24	4	.45	.5	3	.27	.12
Arsenic	4	0	0	4	0	0	4	0	0
Barium	4	.2	0	4	.2	0	4	.2	0
Bicarbonate	4	215.2	19.55	4	102.13	52.17	4	210.3	11.56
Boron	4	.4	.12	4	.25	.11	4	.87	.09
Cadium	4	0	0	4	0	0	4	0	0
Calcium	4	151.25	8.34	4	54.25	1.5	4	226	4.4
Chloride	4	7	.82	4	4	.82	4	7	.82
Chromium	4	.03	.01	4	.03	.01	4	.03	0.1
Conductivity (µmhos/cm at 25°C	4	1513.75	25.62	4	564	12.41	4	1679.25	51.01
Copper	4	.02	0	4	.02	0	4	.02	0
Fluoride	4	.47	.21	4	.45	.05	4	.67	.06
Hardness (as $CaCO_3$)	4	696.5	19.02	4	235	8.29	4	950	20.41
Iron (dissolved)	3	.22	.24	3	.05	.05	3	.03	.01
Iron (total)	4	1.08	1.34	4	:7	1.28	4	.14	.14
Lead	4	.02	0	4	.02	0	4	.02	0
Magnesium	4	79.25	15.31	4	26.25	5.97	4	98.5	15.29
Manganese	4	.49	.06	4	.08	.07	4	.04	.02
Mercury (µg/l)	4	.02	0	4	.02	0	4	.02	0
Molybdenum	4	.2	0	4	.2	0	4	.2	0
Nickel	4	.03	.01	4	.02	0	4	.02	0
Nitrogen - Kjeldahl	4	.88	.1	4	.48	.34	4	.44	.13
Nitrogen - Ammonia	4	.83	.15	4	.23	.15	4	.14	.07
Nitrate as N	1	1.2	0	1	1.95	0	1	6	0
Nitrate + Nitrite as N	3	.71	.87	3	1.93	.7	3	1.82	.15
pH (units)	4	7.4	NA	4	7.41	NA	4	7.49	NA
Phosphorus	4	.03	.03	4	.03	.03	4	.02	.01
Potassium	4	16	1.83	4	8.5	1	4	26.5	3.11
SAR (units)	4	2.04	1.11	4	.74	.08	4	.62	.03
Selenium	4	0	0	4	0	0	4	0	0
Silica	3	14.07	.67	3	15.17	2.67	3	12.97	.85
Sodium	4	123.75	64.4	4	26.5	1.91	4	44.5	2.52
Solids, Total Dissolved	4	1258.75	40.71	4	446.75	56.47	4	1494.75	23.8
Sulfate	4	736	55.72	4	195.75	14.36	4	875.75	32.2
Zinc	4	.04	.01	4	.03	.01	4	.04	.01
Cation-Anion Balance									

a ______________________.
b ______________________.

TABLE 8-13

SUMMARY OF GROUND WATER QUALITY IN SHALLOW AQUIFERS IN THE ROCHELLE COAL MINE PERMIT AREA

	Tongue River Member (7 wells)					Roland Coal (3 wells)					Wasatch Formation (3 wells)				
	No. of Samples	Mean	Std. Dev.	Max.	Min.	No. of Samples	Mean	Std. Dev.	Max.	Min.	No. of Samples	Mean	Std. Dev.	Max.	Min.
FIELD PARAMETERS[a]															
Conductivity (μmhos/cm at 25 (C))	28	2,052.52	779.77	3,776	1,168.2	6	3,132.17	3,974.24	9,585	520	10	1,565.65	319.64	1,911	918
pH (units)	28	6.85	NA	11	6.3	7	7.08	NA	7.5	6.8	10	6.87	NA	7.7	6.4
Water Temperatue (C)	28	75.49	325.05	1,734	10.6	7	12.97	.54	13.7	12.1	10	14.32	3.79	21.6	8.9
LABORATORY PARAMETERS[a]															
Acidity (as $CaCO_3$)[b]	21	-627.62	-140.72	-918	-473	4	703.25	161.55	849	546	0	901.25	-251.35	-1,253	-498
Alkalinity (as $CaCO_3$)	28	674.86	146.89	964	495	10	753.4	148.33	900	570	10	1,011	222.45	1,264	524
Aluminum	27	.6	.88	4	.2	11	.36	.3	1	.1	10	7.61	23.33	74	.2
Arsenic	27	.01	.02	.114	1E-03	11	0	0	.014	1E-03	10	.01	.03	.078	1E-03
Barium	28	.31	.35	2	.2	11	.49	.35	1	.14	10	.54	.28	1.2	.2
Bicarbonate	28	822.79	179.07	1,175	603.5	11	897.18	163.39	1,097	695	10	1,232.63	271.2	1541.1	638.9
Boron	28	.23	.08	.381	.075	11	.18	.09	.275	.01	10	.18	.04	.237	.129
Cadmium	28	0	0	.02	2E-03	11	0	0	.01	2E-03	10	0	0	7E-03	2E-03
Calcium	28	92.58	54.59	202	1.33	11	107.65	51.84	190	49.6	10	52.7	22.75	87	11
Chloride	28	14.5	14.06	53	3	11	7.17	5.28	15.8	.2	10	41.3	27.53	92	12
Chromium	27	.03	.01	.04	.02	10	.05	.03	.1	.02	10	.05	.06	.23	.02
Conductivity (mhos/cm at 25°C	28	2,182.46	689.26	3,810	1346	10	1,809.2	366.6	2,605	1,426	10	1,931.6	329.74	2,700	1,510
Copper	28	.03	.01	.06	.02	11	.02	.01	.04	.01	10	.06	.12	.39	.02
Fluoride	28	.9	.22	1.4	.62	11	1.03	.22	1.31	.78	10	.89	.17	1.14	.63
Hardness (as $CaCO_3$)	28	452.61	243.43	853	67	8	482.38	233.27	838	262	10	273.2	68.11	339	138
Iron (dissolved)	21	.14	.27	1.07	.02	9	.25	.5	1.48	.02	7	.21	.25	.62	.02
Iron (total)	.28	.67	.8	2.77	.03	11	8.03	22.16	74.8	.39	10	12.19	31.78	102	.02
Lead	28	.03	.02	.14	.02	11	.03	.01	.05	.01	10	.08	.19	.63	.02
Magnesium	28	54.21	30.62	121	2	11	53.05	24.28	91	28	10	27.9	12.38	53	9
Manganese	27	.06	.04	.22	.02	11	.05	.07	.237	.01	10	.38	.61	1.97	.02
Mercury (μg/l)	28	.05	.09	.49	.02	11	.07	.18	.61	1E-03	10	.11	.26	.85	.02
Molybdenum	28	.2	0	.2	.2	11	.17	.05	.2	.1	10	.22	.06	.4	.2
Nickel	28	.03	.02	.08	.02	11	.04	.03	.1	.02	10	.05	.07	.25	.02
Nitrogen - Kjeldahl	28	3.77	.99	5.31	1.58	8	2.89	.51	3.9	2.43	10	16.81	45.4	146	1.42
Nitrogen - Ammonia	28	3.5	1.08	5.44	1.39	11	2.81	.52	3.8	2	10	2.18	.77	3.5	1
Nitrate as N	9	1.75	1.29	4.62	1	3	.11	.12	.24	.01	2	1	0	1	1
Nitrate + Nitrite as N	18	.14	.1	.39	.01	6	.97	.09	1.08	.85	8	.1	.1	.26	.01
pH (units)	28	7.86	NA	11.3	7.5	9	7.24	NA	7.8	6.9	10	7.97	NA	8.3	7.6
Phosphorus	28	.04	.06	.28	.01	9	.03	.03	.1	.01	10	.18	.23	.63	.01
Potassium	28	14.11	4.72	23	6	11	13.16	4.39	20.8	2.5	10	15.4	8.17	29	8
SAR (units)	28	8.05	2.15	13.96	3.99	11	5.72	1.34	7.4	4.02	10	10.35	3.84	20.9	7.78
Selenium	28	0	0	2E-03	1E-03	11	0	0	2E-03	1E-03	10	0	0	1E-03	1E-03
Silica	21	6.03	3.51	16.3	3	9	4.58	1.73	5.6	.1	7	23.47	44.07	123	3.7
Sodium	28	366.07	120.75	668	244	11	269.09	29.26	340	239	10	347.2	60.99	410	206
Solids, Total Dissolved	28	1,628	627.75	3,028	843	11	1,248.27	356.22	1,966	800	10	1,240.7	278.09	1,717	697
Sulfate	28	644.86	436.64	1,582	14	11	381.12	353.7	1,016	25	10	68.5	66.42	235	2
Zinc	28	.06	.07	.36	.02	11	.21	.24	.68	.027	10	.2	.46	1.5	.02

a

water inflows were made for the end of each of the first three years of mining. These values represent the maximum ground-water inflow to the pit because the first three years represent the initial opening of the pit and dewatering of the area. That is, for example, all four sides of the pits will be contributing ground water from a previously unstressed system. The area affected by the first three years of mining is shown in Figure 8-7. The spoils from mining will be placed on the west side of the excavated area.

The analytical solution used in developing estimates of ground-water inflow, was developed by Stallman (Ferris et al. 1962) and later summarized by Lohman (1972). The solution is for a confined semi-infinite aquifer bounded by a drain on one side. The head of the drain abruptly lowers a specified amount which results in ground-water discharge to the drain. In the situation where a pit is excavated, the drop in head resulting from opening the pit corresponds to the head drop in the semi-infinite aquifer. The discharge per linear foot of the aquifer to the drain resulting from the drop in drain stage is given as:

$$Q_b = \frac{s_o}{\sqrt{\pi t}} \sqrt{ST}$$

where: s_o = drop in drain stage;
t = time since drop in drain stage;
S = storage coefficient of aquifer; and
T = transmissivity of aquifer.

Using the dimensions of the year 1, 2 and 3 pits (Figure 8-7) and the hydrogeologic properties listed in Table 8-14, ground-water inflow to the pits in gallons per minute (gpm) at the end of each year of

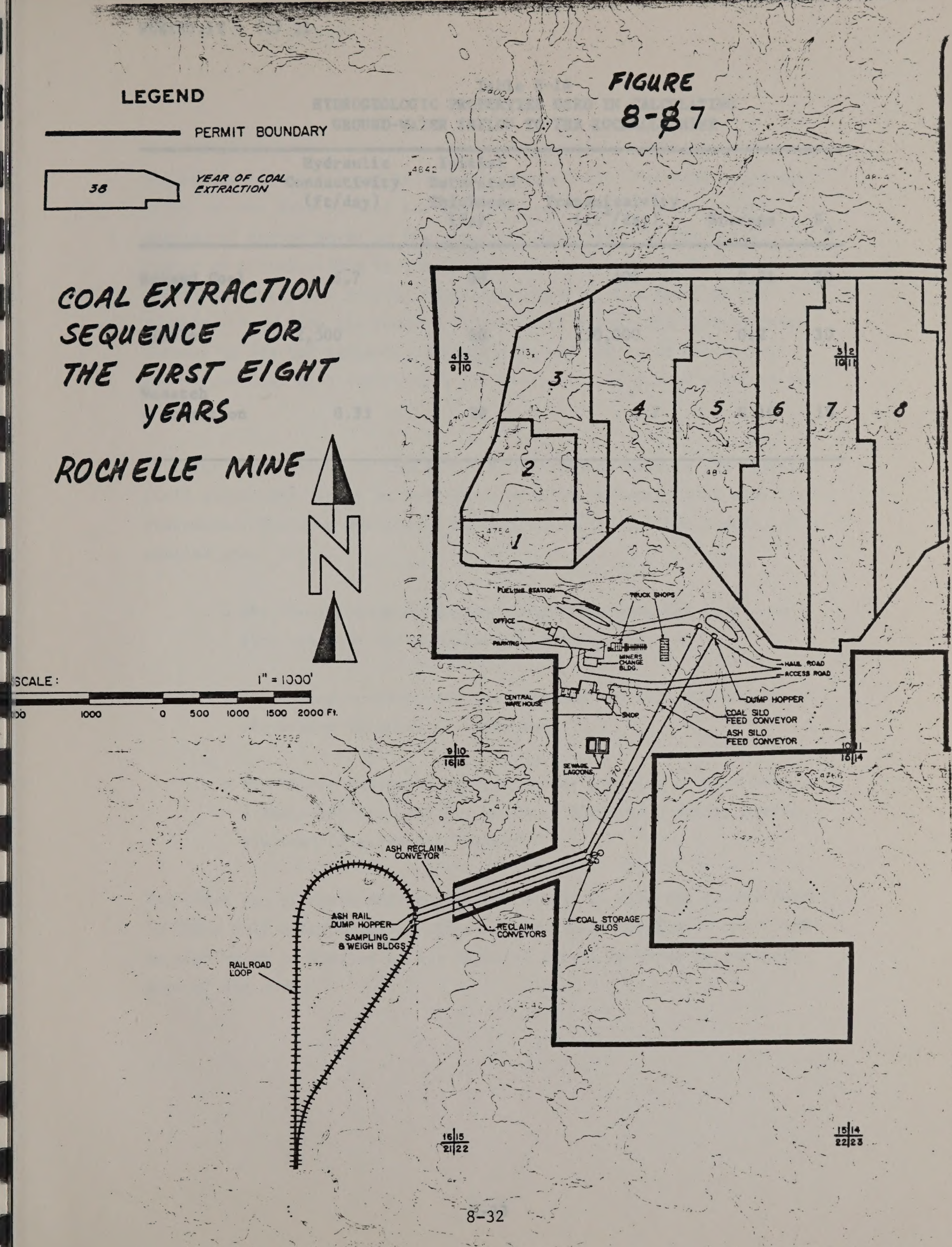


FIGURE
8-~~8~~7
LEGEND
PERMIT BOUNDARY
38
YEAR OF COAL EXTRACTION
COAL EXTRACTION SEQUENCE FOR THE FIRST EIGHT YEARS
ROCHELLE MINE
N
SCALE:
1" = 1000'
1000
0
500
1000
1500
2000 Ft.
1
2
3
4
5
6
7
8
FUELING STATION
OFFICE
PARKING
TRUCK SHOPS
MINERS CHANGE BLDG.
HAUL ROAD
ACCESS ROAD
CENTRAL WAREHOUSE
SHOP
DUMP HOPPER
COAL SILO FEED CONVEYOR
ASH SILO FEED CONVEYOR
SEWAGE LAGOONS
ASH RECLAIM CONVEYOR
ASH RAIL DUMP HOPPER
SAMPLING & WEIGH BLDGS
RECLAIM CONVEYORS
COAL STORAGE SILOS
RAILROAD LOOP

Table 8-14
HYDROGEOLOGIC PROPERTIES USED IN CALCULATING
GROUND-WATER INFLOW TO THE ROCHELLE MINE

	Hydraulic Conductivity (ft/day)	Initial Saturated Thickness (ft)	Transmissivity (ft^2/day)	Storage	S_o
Roland Coal	6.7	60	400	0.01	30
Clinker	2,500	60	150,000	0.2	30
Wasatch Formation	0.33	20	6.7	0.10	10

mining was calculated and is shown in Table 8-15. The most important thing to note here is that the clinker could release significant amounts of ground-water to the mine pit, especially in the early stages of mining. This is due largely to the relatively high hydraulic conductivity and storage (specific yield in this case) of the clinker. Flow from the Wasatch Formation is relatively insignificant because of its low hydraulic conductivity and saturated thickness. The Roland Coal also contributes relatively little ground water to the pit.

The values shown in Table 8-15 are estimates because the specific field conditions cannot be exactly modeled by the analytical equation presented. The main deviations between the field and the theory applied are:

- the theory assumes confined conditions when the formation will actually be unconfined when dewatered;
- the theory assumes that the aquifers are infinite in extent where they probably are not; and
- the theory assumes an instantaneous lowering of head next to a semi-infinite aquifer, while in actuality, during mining the head is gradually lowered.

The first two of these differences would tend to make the values shown in Table 8-15 overestimates. This in particular applies to the clinker zone which is limited in its physical extent as shown by geologic maps of the area.

Table 8-15
SUMMARY OF GROUND-WATER INFLOW CALCULATIONS*
(in gpm)

	Roland Coal	Clinker	Wasatch	Total
YEAR 1	20	1200	10	1200
YEAR 2	30	800	10	800
YEAR 3	40	1000	5	1000

*All calculations should be considered approximate and as upper limits.

Note: Conclusions/limitations concerning calculations in write-up.

8.C.2 Extent of Drawdown and Impacts on Streams and Springs

Roland Coal. The approximate limit of drawdown in the Rochelle Mine area due to excavation and dewatering of the mine is shown in Figure 8-8. For much of the area affected, the extent of drawdown is limited by natural hydrogeologic conditions such as recharge boundaries, discontinuity of hydrogeologic zone, and structural effects.

The limit of drawdown for the mine is mostly controlled by creeks on the southwest, south and east parts of the mine area. Since mining would occur up to the northern extent of the clinker, then dewatering in the clinker would occur until a local drainage was intercepted. Porcupine Creek and a northeastern tributary are shown as limits to the drawdown in the clinker for these areas. In a similar fashion, the West Fork of the Beckwith Greek is shown as the limit to drawdown on the east side of the area. For the northwestern part of the area, the Roland Coal is confined. Calculations using a relationship developed by Stallman (Ferris et al. 1962) indicate that the distance to the line of 1 foot of drawdown in the Roland Coal for this area would be about 4 miles after the first 3 years of mining. In the northeastern part of the area, the extent of the clinker zone probably controls the location of the extent of drawdown, but the location is uncertain. In the northern area, the occurrence of the Roland Coal is less well known and toward the Cordei Fault (see Figure 8-9) may be structurally disturbed. The limit of 1 foot of drawdown in the Roland Coal will be approximately four miles north of the northern extent of the mine area (based on the calculations previously described).

Wasatch Formation. The Wasatch Formation overlies the Roland Coal. The formation is only partially saturated and will contribute only a relatively small quantity of water to the Rochelle mine. Using the properties for the Wasatch Formation presented in the section on

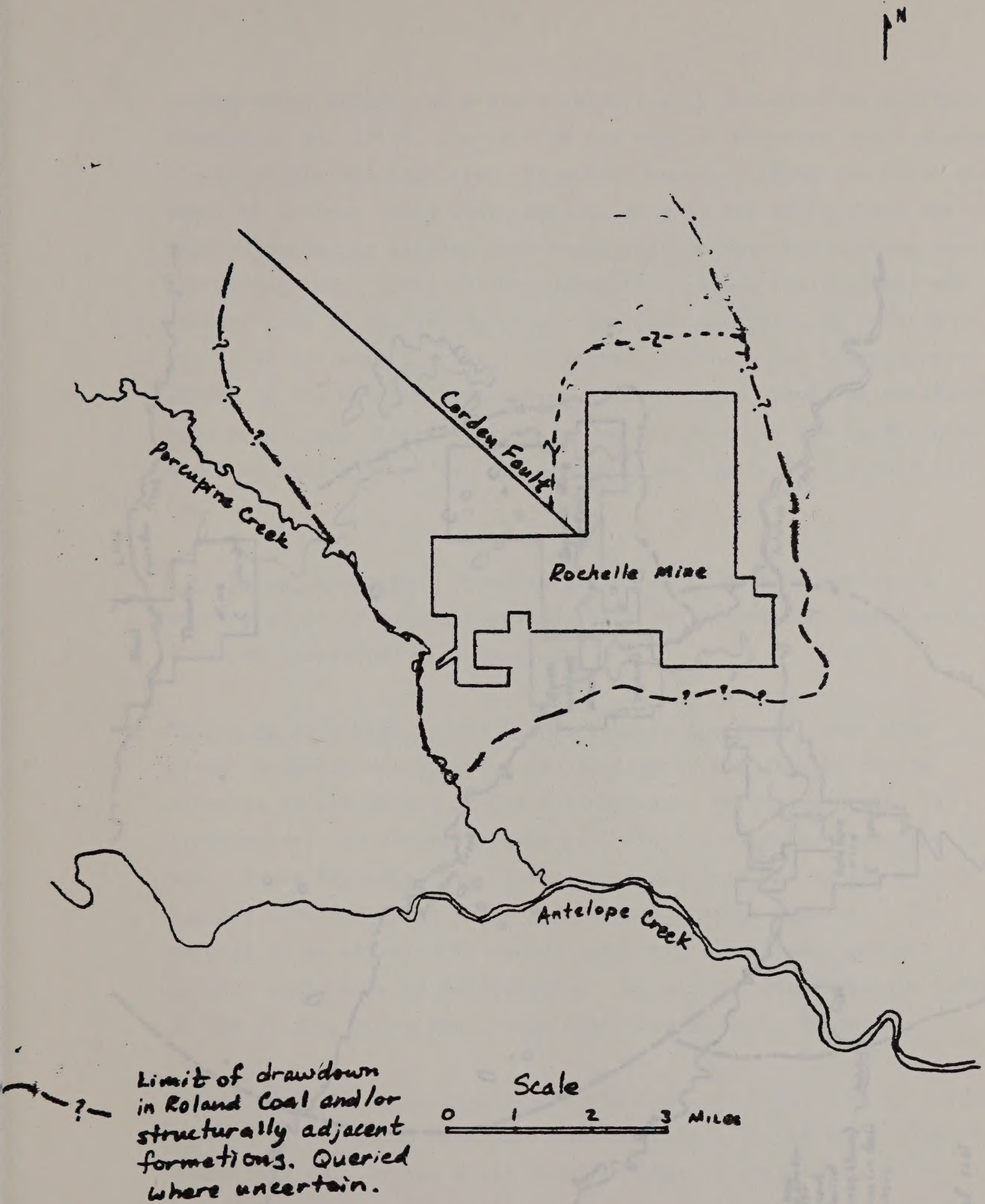


Figure 8-8. Approximate maximum Limit of Drawdown for Roland Coal and/or Structurally Adjacent Formations for the period of existence of Rochelle Mine.

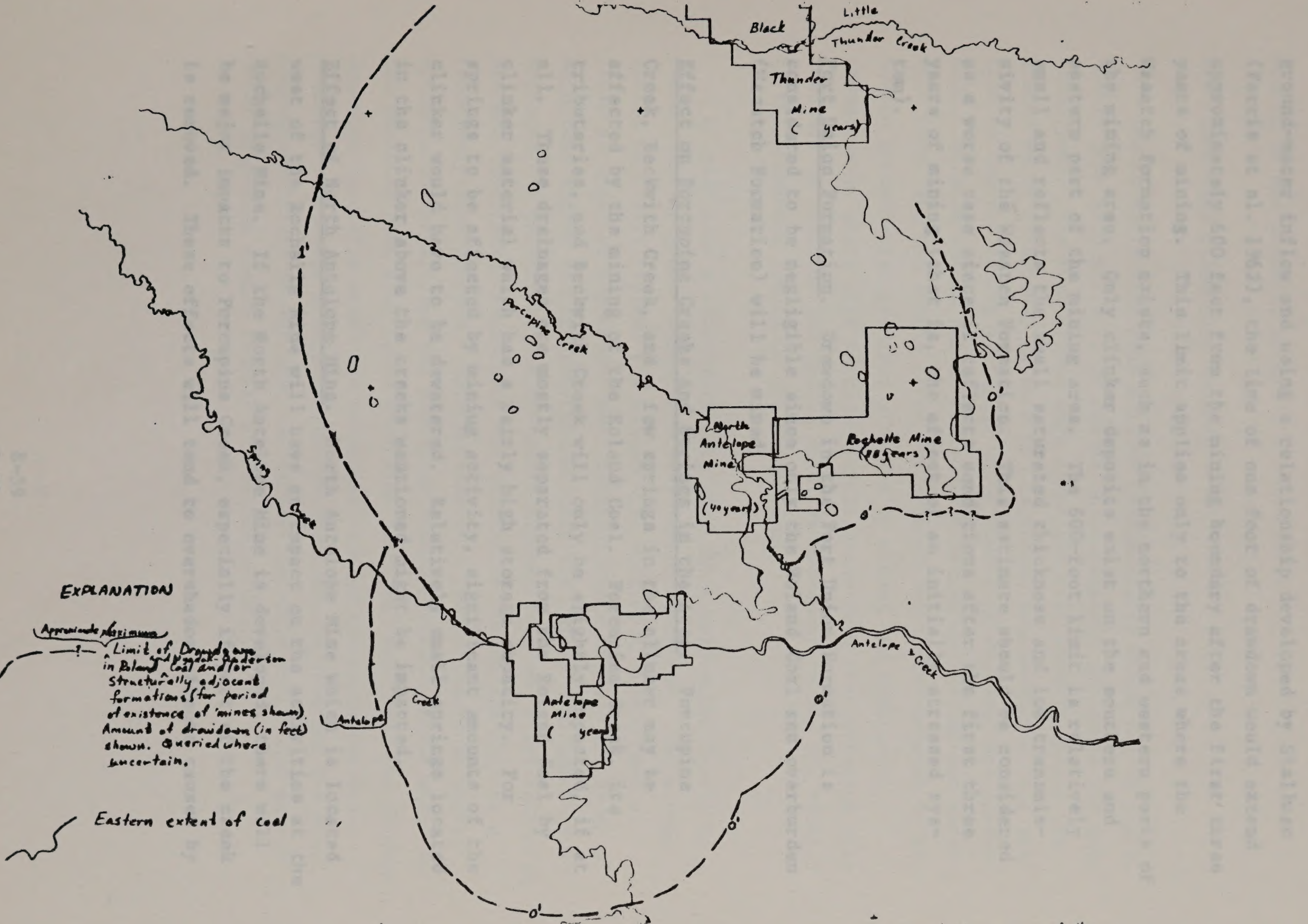


Figure ~~8-10~~ Approximate maximum Limit of Drawdown for Roland and Wyodak-Anderson Coal and/or Structurally adjacent Formations for the period of existence of the Rochelle, North Antelope, and Antelope Mines

8-9

ground-water inflow and using a relationship developed by Stallman (Ferris et al. 1962), the line of one foot of drawdown would extend approximately 600 feet from the mining boundary after the first three years of mining. This limit applies only to the areas where the Wasatch Formation exists, such as in the northern and western parts of the mining area. Only clinker deposits exist on the southern and eastern part of the mining area. The 600-foot limit is relatively small and reflects the small saturated thickness and low transmissivity of the Wasatch Formation. This estimate should be considered as a worse case since it reflects conditions after the first three years of mining (that is, the effect of an initially stressed system).

Fort Union Formation. Drawdown in the Fort Union Formation is considered to be negligible since only the Roland Coal and overburden (Wasatch Formation) will be mined.

Effect on Porcupine Creeks and Springs in the Area. Porcupine Creek, Beckwith Creek, and a few springs in the clinker may be affected by the mining of the Roland Coal. Porcupine Creek, its tributaries, and Beckwith Creek will only be slightly impacted, if at all. These drainages are mostly separated from the Roland Coal by clinker material which has a fairly high storage capacity. For springs to be affected by mining activity, significant amounts of the clinker would have to be dewatered. Relatively small springs located in the clinker above the creeks mentioned might be impacted.

Effect of North Antelope Mine. North Antelope Mine which is located west of the Rochelle Mine will have an impact on the activities at the Rochelle Mine. If the North Antelope Mine is developed, there will be major impacts to Porcupine Creek, especially if part of the creek is removed. These effects will tend to overshadow effects caused by

mining at the Rochelle Mine.

8.D LONG-TERM HYDROLOGIC IMPACTS

The Rochelle Mine area will be incrementally mined for 38 years. Spoils from each pit will be placed in an adjacent pit mined the previous year. The area around each mined pit will locally affect the ground water (drawdown) as each pit is opened and dewatered (see section on impacts during mining in which limits of drawdown are discussed). As each opened pit is filled with mining spoils, ground water will flow into the spoils (from surrounding sediments) because of the inward ground-water gradient produced by mining and dewatering. Ground water along with vertical infiltration from precipitation will continue to recharge the spoils until ground-water levels are similar to the premining levels of the Roland Coal.

It will take a relatively long time for ground-water levels to reach their original premining steady-state conditions. The mining spoils that will replace the Roland Coal will most likely have at least an order of magnitude lower hydraulic conductivity and order of magnitude higher storage coefficient than the Roland Coal which it replaces. A relatively low hydraulic conductivity and relatively high storage coefficient means that the filling of the spoils will be a relatively slow process. This process will take at least 40 years, which is the total time for mining at Rochelle Mine. Ground water in the Rochelle Mine area flows generally north and west from the clinker deposits (recharge area) and hence west toward the Porcupine Creek drainage (discharge area). A similar condition is expected for post-mining conditions except that the clinker deposits will yield ground water to mining spoils instead of the Roland Coal.

8.D.1 Possibility of Contamination of Nearby Surface Water

Since Porcupine Creek has been identified as the local ground-water discharge area for the Rochelle Mine, there exists the possibility of the contaminaton of its water from mining activity. A worse case scenario was developed for the Rochelle Mine in which the travel time has been estimated for contaminants traveling from the farthest western part of the Rochelle Mine to Porcupine Creek.

The following well known equation was used (a modification of Darcy's law) to determine a ground-water velocity in the Roland Coal between the Rochell Mine and Porcupine Creek:

$$v = \frac{K\,\Delta h/\Delta x}{n}$$

where

K = hydraulic conductivity,
$\Delta h/\Delta x$ = hydraulic gradient, and
n = porosity.

Using a hydraulic conductivity of 6.7 ft/day, a hydraulic gradient of about 20 feet per mile, and a porosity of 0.1 to 0.01, then an average ground-water velocity of approximately 2.5 ft/day can be calculated. The distance from the west end of the planned Rochelle Mine to Porcupine Creek is about one mile. Thus it would take about 6 to 60 years for a contaminant to reach Porcupine Creek after mining spoils are placed in the first excavated pit. This should be considered a worst case condition since the Roland Coal may have a larger porosity. Note that the above calculations do not incorporate chemical dispersivity or chemical reactions.

8.E LONG-TERM WATER QUALITY IMPACTS

The primary water quality effect resulting from surface coal mining operations is expected to be an increase in the total dissolved solids of both subsurface and surface water flows (McWhorter et al. 1979; Skogerboe et al. 1979; Van Voast 1974, 1975, 1977). The major constituents in surface and subsurface runoff from the spoils are sodium, calcium, magnesium, sulfate, and bicarbonate (McWhorter et al. 1975). Increases in dissolved soils may be dependent on the extent of weathering that the disrupted strata of the mine area have undergone. For recently exposed strata, increases in sodium, alkalinity, and sulfate are predominant. For strata that have been exposed longer, calcium, magnesium, alkalinity and sulfate predominate. Apparently, calcium and magnesium salts may control long-term effects on water quality (Skogerboe et al. 1979).

Important mineral phases containing these elements include calcite, dolomite, gypsum, and starkeyite, among others. Other important mineral phases may include pyrite, feldspars, quartz, and the clay minerals. Clay minerals are especially important as they can act as chemical sponges, exchanging and absorbing undesirable heavy metals and releasing less toxic ones.

A reliable, and probably conservative, estimate of the potential salt production from the overburden spoils can be obtained by chemical analysis of saturated paste extracts. Extensive chemical analysis of a number of overburden cores from the Rochelle have been made. A statistical analysis of these results is presented in Table 8-16. If these values are representative of postmining overburden water quality, they indicate that post-mining dissolved solids concentrations could be somewhat greater than one and a half times premining dissolved solids concentrations in either the Wasatch Formation or the

TABLE 8-16

CHEMICAL ANALYSIS OF SATURATED PASTE EXTRACTS OF OVERBURDEN SAMPLES

Parameter	Average	Minimum	Maximum
Conductivity, mmhos	2.56	1.17	6.47
Sodium, meq/l	12.02	5.85	33.60
(mg/l)	(276)	(135)	(773)
Calcium, meq/l	7.60	4.10	14.19
(mg/l)	(152)	(82)	(284)
Magnesium, meq/l	12.63	3.10	51.44
(mg/l)	(153)	(38)	(625)
Boron, ppm	0.62	0.04	1.19
Molybdenum, ppm	2.04	1.46	2.83
Selenium, ppm	0.16	0.00	0.41

Source: Rochelle Coal Company 1981.

Roland coal seam. From these tests, it appears that calcium and magnesium concentrations would be greater than found in premining ground water, while sodium concentrations may decrease slightly. Although not measured, it is likely that sulfate and bicarbonate concentrations would also increase. As far as trace elements are concerned, their redistribution as a result of surface mining and reclamation may occur through one or more of the following processes (NRC 1980).

- Physical relocation
- Mechanical breakup (fragmentation) of previously consolidated material that increases the surface area of rock so the rock and minerals are more exposed to weathering and subsequent trace-element mobilization
- Major changes in the porosity and permeability of rock material, with a consequent increase in the rate and amount of water that moves through near-surface aquifers
- Change from chemically reducing conditions to oxidizing conditions, which alter the solubility by conversion to the oxidixed forms of the trace elements
- Oxidation of pyrite and release of acid, thereby enhancing solubility and mobilization of trace elements

In general the interdependence of overburden characteristics, the availability and composition of ground water as a transport medium, and the method of overburden removal and replacement makes the analysis of potential trace-element redistribution a site-specific problem. Skogerboe et al. (1979) found that concentrations of aluminum, chromium, and lead were consistently below detection limits and the EPA's Interim Primary Drinking Water Standards (IPDWS). Measurable levels of selenium, mercury and arsenic were detected, but all measurements were below IPDWS levels. Measurements of manganese, zinc and copper were low and below EPA's Secondary Drinking Water

Standards (SDWS). Measurements of iron were above the SDWS. If these results have any relationship to this mine, trace element concentrations can be expected to be low and not significantly different from ambient levels.

The water quality effects of waste solids disposal within the spoils are difficult to predict at this time. Detailed waste characterization and leaching studies are now being performed on samples produced from the SASOL gasification plant in South Africa and a U.S. coal-fired power plant. During the SASOL test, sampling and analysis of a number of waste streams including input coal, gasifier ash, bioxidation sludge, by-product tar, by-product oil, by-product phenol, evaporator brine, evaporator condensate, raw gas liquor, and stripped gas liquor will be performed. In lieu of these test results, it is possible to make a preliminary evaluation of potential water quality degradation by evaluating the potential effects of the disposal of each of the individual wastes separately. This is necessary because information on the chemical quality of leachate from all the wastes combined is presently not available.

The best available estimate of the quality of gasification ash lechate was developed from a leaching study performed in 1979 by Peabody Coal Company. Gasification ash comprises about 70 percent of the waste solids by weight that are planned for final disposal in the mine site. In this test, 200 grams of gasifier ash, resulting from the gasification of Big Sky, Montana coal was slurried with 400 grams of distilled demineralized water. Elemental analyses of the filtrate were made after one and two weeks. The average results of these tests are listed in Table 8-17.

Comparing these average values with the average values of similiar constituents in area ground waters indicates that the levels

TABLE 8-17

COMPARISON OF MEAN LEACHATE QUALITY WITH MEAN QUALITY OF PREMINING GROUND WATERS FROM ROCHELLE MINE

Parameter	Average Results of Leaching Studies: Gasifier Ash	Average Results of Leaching Studies: Overburden	Average Results of Leaching Studies: Gasifier Ash/ Overburden	Wasatch Formation Ground Water Quality	Roland Coal Ground Water Quality
Aluminum (μg/l)	590	4,240	1,000	7,610	360
Ammonia (as N) mg/l	0.2	1.0	1.0	2.18	2.81
Arsenic (μg/l)	1	3	10	10	0.0
Boron (mg/l)	57.1	ND	ND	0.18	0.18
Cadmium (μg/l)	3	5	5	0	0.0
Calcium (mg/l)	518	14	28	52.7	107.65
Chloride (mg/l)	12	5	4	41.3	7.17
Chromium (μg/l)	18	17	10	50	50
Copper (μg/l)	16	32	16	60	20
Fluoride (mg/l)	11.5	0.08	4.34	0.89	1.03
Iron (μg/l)	90	1,710	260	12,190	8,030
Lead (μg/l)	100	20	10	80	30
Magnesium (mg/l)	1.1	9.7	10.6	27.9	53.05
Manganese (μg/l)	15	40	15	380	50
Mercury (μg/l)	0.32	0.23	0.11	0.11	0.07
Molybdenum (μg/l)	2,450	65	640	220	170
Nickel (μg/l)	8	15	15	50	40
Nitrate (as N) mg/l	0.2	0.5	0.4	0.1	0.97
pH	--	--	--	--	--
Potassium (mg/l)	8.4	8.8	7.5	15.4	13.16
Selenium (μg/l)	1	5	13	0	0
Sodium (mg/l)	16.4	58.8	68.6	347.2	269.1
Zinc (μg/l)	26	146	84	200	210

Source: Rochelle Coal Company, 1981.

of aluminum, arsenic, boron, cadmium, calcium, chloride, fluoride, lead, mercury, molybdenum, nitrate and selenium were greater than premining Roland coal or Wasatch ground waters. The levels of boron, cadmium, calcium, fluoride, lead, mercury, molybdenum, and selenium were above the levels of both premining ground waters.

Comparing contaminant values in Table 8-17 with applicable water quality standards amd criteria listed in Table 8-18 indicates that the levels of boron, fluoride, molybdenum, and possibly lead in gasification leachate may cause water quality problems. An idea of the potential attenuation of these contaminants can be gained by examining the batch leaching test of the ash/overburden mixtures. The concentrations of all these constituents were reduced, although only boron and lead were reduced to levels below the applicable standard/criterion.

The relative movement of the undiluted contaminant front can be estimated through the use of distribution and retardation coefficients. Because the appropriate batch or column leaching tests have not been performed, distribution coefficient values must be extracted from the literature. This is a problematic approach because distribution coefficients are specific to the chemical and physical properties of the solids and solutions involved. Nevertheless, estimated distribution and retardation coefficients are presented in Table 8-19.

These results would indicate that the movement of these materials through the overburden would be attenuated. Relative to the movement of water, the degree of attenuation would range from 25 times for molybdenum to 10,000 times for lead.

Another aspect of the potential water quality degradation resulting from disposal of gasifier ash is the increase in TDS of the

TABLE 8-18

APPLICABLE WATER QUALITY STANDARDS AND CRITERIA

Parameter	Interim Primary[a] Drinking Water (mg/liter)	Secondary[b] Drinking Water (mg/liter)	Livestock[c] (mg/liter)	Irrigation[c] (mg/liter)
Aluminum	--	--	5.0	5.0
Arsenic	0.05	--	0.2	0.1[d]
Barium	1.0	--	--	--
Beryllium	--	--	--	0.1-0.5[d]
Boron	--	--	5.0	0.75[d]
Cadmium	0.01	--	0.05	0.01
Chloride	--	250	--	--
Chromium	0.05	--	1.0	0.1
Copper	--	1.0	0.5	0.2
Cyanide	--	0.2	--	--
Fluoride	1.4-2.4	--	2.0	1.0
Iron	--	0.3	--	5.0
Lead	0.05	--	0.05-0.1	5.0
Lithium	--	--	--	2.5
Manganese	--	0.05	--	0.2
Mercury	0.002	--	0.01	--
Molybdenum	--	--	--	0.01
Nickel	--	--	--	0.2
Nitrâte nitrogen	10.0	--	100.0	--
pH	--	6.5-8.5	--	--
Selenium	0.01	--	0.05	0.02
Silver	0.05	---	--	--
Sulfate	--	250	--	--
Vanadium	--	--	0.1	0.1
Zinc	--	5.0	25.0	2.0
Total Dissolved Solids		500		

[a]40 CFR Part 141

[b]40 CFR Part 143

[c]NAS, 1972

[d]U.S. EPA, 1976

TABLE 8-19

ESTIMATED DISTRIBUTION AND RETARDATION COEFFICIENTS FOR BORON, FLUORIDE, LEAD AND MOLYBDENUM

Parameter	Distribution Coefficient (ml/gm)	Retardation[3]
Boron[1]	12	0.017
Fluoride[1]	17	0.012
Lead[2]	4,000	0.0001
Molybdenum[2]	5	0.040

[1] Derived from adsorption experiments by Glaze and Runnels, 1980

[2] Battelle Northwest Laboratories, 1974.

[3] Based on a porosity of 0.2 and a bulk density of 60 lb/ft^3

leachate from ash compared with background water quality. Conductivity or TDS measurements were not made for the gasifier ash leachate previously presented. Other studies (Griffen 1980) would indicate that the total dissolved solids content of leachate from gasifier ash leachate would be lower than that expected to result from overburden dissolution.

Other large volume wastes that are to be returned to the mine site for final disposal include boiler bottom and fly ash and flue-gas desulfurization sludge. It presently is expected that about 18 percent of the waste stream to the mine at full gasification plant capacity would be fly ash. Boiler bottom ash is expected to represent about 4 percent of the total mine-directed waste stream. An example of leachate from the expected boiler ash composition (80 percent fly ash and 20 percent bottom ash) is shown in Table 8-20. Also included in the table are the results of some column leaching studies done on fly ash samples produced by the Wyodak power plant using coal from the Wyodak coal mine near Gillette, Wyoming. The results for the ash leachate indicate that the average concentrations of arsenic, boron, cadmium, chromium, fluoride, selenium, zinc, and copper may be greater than that found in premining ground waters. A comparison of the leachate levels with applicable water quality standards and criteria listed in Table 8-18 indicates that: 1) boron levels may exceed livestock and irrigation usage criteria; 2) chromium levels may exceed drinking water standards; 3) fluoride levels may slightly exceed irrigation and livestock criteria and drinking water standards, and 4) selenium levels may slightly exceed drinking water standards. The potential for boron and fluoride attenuation in overburden has already been presented. The retardation coefficients for selenium and chromium are probably similiar. A measured retardation coefficient for selenium was slightly smaller than that listed previously for fluoride. Total dissolved solids concentrations in ash leachate will

TABLE 8-20

COMPARISON OF MEAN ASH LEACHATE QUALITY

Parameter[a]	Ash Leachate 80% Fly Ash/ 20% Bottom Ash[b]	100% Fly Ash Leachate[c]	Flue-gas Desulfurization Sulfur Leachate[b]	Wasatch Formation Ground Water Quality	Roland Coal Ground Water Quality
Specific Conductance	--	2,750	--	1,565	3,132
Total Dissolved Solids	--	2,092	--	1,241	1,248
Chloride	--	32	--	41.3	7.17
Sulfate	--	1,213	--	68.5	381
Alkalinity	--	233	--	1,011	753
Bicarbonate	--	254	--	1,233	897
Carbonate	--	3	--	--	--
Calcium	--	187	--	52.7	108
Magnesium	--	107	--	27.9	53.05
Potassium	--	66.8	--	15.4	13.16
Sodium	--	283	--	347.2	269
<u>Trace Elements</u>					
Arsenic	0.034	0.01	0.03	0.01	0.0
Barium	--	--	0.7	0.54	0.49
Beryllium	0.001	--	0.002	--	--
Boron	5.7	0.88	2.52	0.18	0.18
Cadmium	0.005	0.01	0.001	0.0	0.0
Chromium	0.107	0.13	0.004	0.05	0.05
Fluoride	1.9	0.4	12.35	0.89	1.03
Germanium	0.01	--	0.01	--	--
Mercury	0.005	0.001	0.001	0.11	0.07
Lead	0.011	0.009	0.004	0.08	0.03
Manganese	0.002	0.017	0.002	0.38	0.05
Molybdenum	0.05	0.02	0.053	0.22	0.17
Nickel	0.03	0.02	0.05	0.05	0.04
Selenium	0.014	0.01	0.043	0.0	0.0
Vanadium	0.1	0.6	0.01	--	--
Zinc	0.084	0.02	0.043	0.2	0.21
Copper	0.043	0.02	0.024	0.06	0.02

[a] All concentrations in mg/l unless otherwise indicated.
[b] Radian Corporation, 1975.
[c] Rochelle Coal Company, 1981.

likely be similar to that of post-mining ground water if leaching results from Wyodak power plant fly ash are representative (Table 8-20).

Flue-gas desulfurization (FGD) wastes are expected to amount to about 5 percent of the solid wastes returned to the mine site. An example of leachate quality is listed in Table 8-20. The levels of the following water quality constituents in FGD sludge leachate may exceed premining ground water quality: 1) arsenic, 2) barium, 3) cadmium, 4) fluoride, 5) molybdenum, 6) nickel, and 7) selenium. Comparing the average concentrations of these constituents with the applicable standards and/or criteria shows that 1) the boron level exceeds the irrigation criteria; 2) the fluoride concentration exceeds drinking water standards and irrigation and livestock water quality criteria; 3) the molybdenum level exceeds the irrigation criteria; and 4) selenium exceeds the drinking water standards and irrigation criteria. It is expected that the TDS concentration in FGD sludge leachates would be several times higher than that expected in post-mining ground waters (Aerospace Corporation 1979).

In summary the concentrations of boron, fluoride, molybdenum, and possibly selenium are most likely to be found above both postmining ground water quality. The information necessary to define the potential transport of these constituents is presently not available. As mentioned previously, this data will be developed before the end of 1981. Using the results of leachate-soil interactions containing these parameters, but not necessarily involving similar solids or liquids, estimates of the attentuation potential of these parameters have been presented. Based on these results, the attenuation of molybdenum is expected to be about 25 times slower than the rate of movement of ground water, while the attentuation of the other parameters is expected to range from 60 to 100 times slower than the rate

of ground water movement. Elevated concentrations of trace metals will not be detectable in ground water discharging to Porcupine Creek for several thousands of years after mining ceases.

8.F CUMULATIVE IMPACTS

8.F.1 Extent of Drawdown in Roland Coal

The limits of drawdown in the Roland Coal and the stratigraphically equivalent Wyodak-Anderson Coal which will be mined in three other mines in the area around Rochell Mine are shown in Figure 8-9. These mines include the Black Thunder to the north, North Antelope to the west, and Antelope to the southwest. The limit of drawdown for the Rochelle Mine is shown in Figure 8-8. The maximum limit of drawdown for the Antelope Mine was calculated at three miles from the mine site (Antelope Coal Company 1981). The limit of one foot of drawdown is shown for the North Antelope Coal Mine as was calculated by the North Antelope Coal Company (1981). For the Black Thunder Mine, the limit of drawdown is taken as near the eastern boundary of the limit of the coal. The exact extent of the clinker is unknown, but is probably not too far east of the boundary of the coal.

After the completion of mining, the ground-water systems in the vicinity of Rochelle Mine, North Antelope Mine and Antelope Mine will reach a steady state similar to premining conditions. The spoils in the mining pit will then contribute similar quantities of ground water to the local drainages. For the Rochelle Mine, approximately 10 to 40 gpm are estimated to flow to Porcupine Creek from the spoils. These calculations were made using Darcy's law assuming that the Roland Coal has a hydraulic conductivity of 50 gpd/ft^2 and a storage of 0.01. The area of inflow is approximately one mile by 60 feet high. For the North Antelope Mine, approximately 44 gpm are estimated to discharge from the spoils to Porcupine Creek. For the Antelope Coal Mine,

approximately 160 gpm are estimated to discharge from the spoils to Antelope Creek. Thus the total estimated flow of ground water from spoils to Antelope Creek below its confluence with Porcupine Creek is 200 gpm (0.4 cfs).

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WCHY.AA (I) 1 TECHRPT

IN THE MATTER OF THE PETITION FOR CHANGE IN THE USES SPECIFIED FOR WATER STORED IN LaPRELE RESERVOIR FROM IRRIGATION AND DOMESTIC TO IRRIGATION, DOMESTIC AND INDUSTRIAL AND FOR A PARTIAL CHANGE IN POINT OF DIVERSION FOR A PORTION OF THE STORED WATER UNDER PERMIT NOS. 728 RES. AND 1581 RES., SUPPLIED FROM LaPRELE CREEK.	DOCKET NUMBER [illegible] IN WATER DIVISION NUMBER ONE

PETITIONERS: THE DOUGLAS RESERVOIRS WATER USERS ASSOCIATION
P. O. BOX 135, DOUGLAS, COUNTY OF CONVERSE, WYOMING 82633

PANHANDLE EASTERN PIPE LINE COMPANY
3000 BISSONNET AVENUE, P. O. BOX 1642, HOUSTON, TEXAS 77001

This matter was considered by the State Board of Control at a special meeting on 3 January 1975, with the following results:

FINDINGS OF FACT

APPENDIX A

1. The Board of Control has the jurisdiction both to consider the petitioners' request for change in uses and partial change in point of diversion, and to prepare and promulgate the Order hereinafter set forth disposing of said petition.

2. The members of the Douglas Reservoirs Water Users Association are the owners of the LaPrele Dam and Reservoir which is located in Sections 31, 32, 33 and 34, Township 32 North, Range 73 West, and Sections 4 and 5, Township 31 North, Range 73 West in Converse County.

3. The reservoir appropriations involved are also owned by the Association members and are identified as follows:

a. The Douglas Reservoirs Company Appropriation, Permit No. 728 Res., the LaPrele Reservoir storing water from LaPrele Creek, tributary North Platte River, priority September 21, 1905; and of record in Order Record 6, Page 98, Certificate Record 42, Page 455, Proof No. 17283, for the storage of 15,106 acre-feet for irrigation and domestic purposes.

b. The Douglas Reservoirs Company Appropriation, Permit No. 1581 Res.Enl. of the LaPrele Reservoir, priority July 3, 1909, and of record in Order Record 6, Page 98, Certificate Record 42, Page 455, Proof No. 17284, for the storage of 4,894 acre-feet for irrigation and domestic purposes.

These two permits authorize storage of a total of 20,000 acre-feet in LaPrele Reservoir.

4. Petitioners request that the two appropriations above described be amended to add a preferred use, namely industrial use to the present domestic and irrigation uses, and further request that a change in the point of diversion and means of conveyance be allowed.

(Typed from very poor quality copy - some numbers may be inaccurate.)

IN THE MATTER OF THE PETITION FOR CHANGE IN THE USES) SPECIFIED FOR WATER STORED IN LaPRELE RESERVOIR FROM) IRRIGATION AND DOMESTIC TO IRRIGATION, DOMESTIC AND) INDUSTRIAL AND FOR A PARTIAL CHANGE IN POINT OF) DIVERSION FOR A PORTION OF THE STORED WATER UNDER) PERMIT NOS. 728 RES. AND 1581 RES., SUPPLIED FROM) LaPRELE CREEK.)	DOCKET NUMBER I-74-2-7 IN WATER DIVISION NUMBER ONE

PETITIONERS: THE DOUGLAS RESERVOIRS WATER USERS ASSOCIATION
P. O. BOX 115, DOUGLAS, COUNTY OF CONVERSE, WYOMING 82633

PANHANDLE EASTERN PIPE LINE COMPANY
3000 BISSONNET AVENUE, P. O. BOX 1642, HOUSTON, TEXAS 77001

This matter was considered by the State Board of Control at a special meeting on 3 January 1975, with the following results:

FINDINGS OF FACT

1. The Board of Control has the jurisdiction both to consider the petitioners' request for change in uses and partial change in point of diversion, and to prepare and promulgate the Order hereinafter set forth disposing of said petition.

2. The members of the Douglas Reservoirs Water Users Association are the owners of the LaPrele Dam and Reservoir which is located in Sections 21, 17, 28, 32, 33 and 34, Township 32 North, Range 73 West, and Sections 4 and 5, Township 31 North, Range 73 West in Converse County.

3. The reservoir appropriations involved are also owned by the Association members and are identified as follows:

a. The Douglas Reservoirs Company Appropriation, Permit No. 728 Res., the LaPrele Reservoir storing water from LaPrele Creek, Tributary North Platte River, priority September 21, 1905; and of record in Order Record 6, Page 98, Certificate Record 42, Page 455, Proof No. 17283, for the storage of 15,106 acre-feet for irrigation and domestic purposes.

b. The Douglas Reservoirs Company Appropriation, Permit No. 1581 Res.Enl. of the LaPrele Reservoir, priority July 7, 1909, and of record in Order Record 6, Page 98, Certificate Record 42, Page 456, Proof No. 17284, for the storage of 4,894 acre-feet for irrigation and domestic purposes.

These two permits authorize storage of a total of 20,000 acre-feet in LaPrele Reservoir.

4. Petitioners request that the two appropriations above described be amended to add a preferred use, namely industrial use to the present domestic and irrigation uses, and further request that a change in the point of diversion and means of conveyance be allowed.

5. This petition was referred to a public hearing by unanimous agreement of the members of Board of Control arrived at by means of a mail ballot dated 24 September 1974. Said hearing was held at Douglas, Wyoming on the 19th of November 1974. Due and legal notice of the time and place of the hearing was published in the Douglas Budget on the 17th of October 1974. In addition, notice of this hearing was given by certified mail to those appropriators who might be affected, by the Superintendent of Water Division One, who also conducted the hearing.

6. All members of the Board of Control were present at the public hearing, as were the petitioners appearing by their attorneys and many others being represented by attorneys or by themselves.

7. Evidence produced by the petitioners at the hearing, and now part of the record, established the following facts:

a. An agreement between the Association and Panhandle Eastern was introduced (Exhibit 4) as evidence. Under this agreement dated the 28th of May 1974 Panhandle Eastern Pipe Line Company agrees to purchase and the Association agrees to sell 5,000 acre-feet per year of water stored in LaPrele Reservoir. In the event that during any irrigation season there is insufficient water impounded in the reservoir to satisfy the needs of both parties, then the available water shall be apportioned three fourths (3/4) to the Association and one fourth (1/4) to Panhandle Eastern. The agreement calls for up to 2,500 acre-feet of water to be delivered for the period beginning October 1 and continuing through April 30 of the next succeeding year (winter season), if available on a reasonably uniform basis, and for the period from May 1 through September 30 (irrigation season), the difference between actual deliveries during the preceeding winter season and 5,000 acre-feet on a reasonably uniform basis as set by schedules submitted by Panhandle Eastern.

b. The stored water purchased by Panhandle Eastern will be conveyed down LaPrele Creek to the North Platte River and will be diverted from North Platte River through the Panhandle Pipeline No. 1, Permit Nos. 24403, 6523 Enl. and 6324 Enl. with point of diversion located South 20° 21' East, 3,169 feet from the northwest corner of Section 7, Township 33 North, Range 71 West and situated in Lot 5 of said Section 7. From this point the water will be conveyed through the Panhandle Pipeline No. 1 to the Panhandle Reservoir No. 1. Water stored in the Panhandle Reservoir No. 1 will be used for industrial purposes by Panhandle Eastern in the operation of a coal gasification plant to be constructed at either of two plant sites described in petitioner's Exhibit 5. One possible site is within Townships 41 and 42 North, Range 71 West, located in Campbell County, the other is within Township 35 North, Range 70 West, located in Converse County.

c. The State Engineer, in a letter dated February 23, 1971, to the Douglas Reservoirs Water Users Association, restricted the present storage capacity of LaPrele Reservoir to 10,000 acre-feet in any one year, due to the deteriorated condition of LaPrele dam. This restriction is still in effect.

d. In order to carry out the terms of the agreement discussed above, it will be necessary to rehabilitate the LaPrele Dam so the storage restriction may be removed and the capacity made available for the storage of 20,000 acre-feet as originally adjudicated. Petitioners presented a feasibility report (Exhibit 10) which concluded that the rehabilitation of LaPrele Dam is feasible and the use of the full capacity can be restored at an approximate cost of $4.975 million dollars.

e. The President of the Association testified that the Corps of Engineers had notified the state that the dam was unsafe, and that the Association, over the past several years, had been unable to obtain financing to rehabilitate the LaPrele Dam. He further testified that if the rehabilitation is not accomplished the dam will, in fact, become unusable and no water will be stored in LaPrele Reservoir.

f. A map showing all of the lands covered by the secondary permits entitled to water from the LaPrele Reservoir, the amount thereof and ownership of such lands by name was introduced by petitioners (Exhibit 8).

g. In conjunction with the map, Exhibit 9 was introduced which is a group exhibit of the "Consent, Agreement and Subordination" forms executed by those landowners holding secondary permits or portions thereof. These secondary permit numbers were adjudicated as follows: 1430 Enl, ... etc. The evidence presented indicated that there were 11,236.48 acres of land entitled to storage water under these permits and that the owners of all of these rights have filed consents to the change. (See paragraph 9e of this Order for clarification of acreage irrigated under these permits.)

8. Evidence produced at the hearing by other than the petitioners and now part of the record established the following facts:

a. The Upper LaPrele Water Users introduced a statement by Mr. Robert Cross. He stated that historically the appropriators above the dam on LaPrele Creek have been using 1 c.f.s. per 70 acres for their irrigating together with an additional 1 c.f.s. from surplus water in the creek during the period from approximately April 15 through July 15 of each year. His concern was that the agreement between Panhandle Eastern and the Association could reduce the amount of water historically available to the Upper LaPrele Creek water users.

b. There were two other parties who, while not protesting the granting of the petition, did pose questions pertaining to how the agreement would affect their

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b. There were two other parties who, while not protesting the granting of the petition, did pose questions pertaining to how the agreement would affect their

particular operations. Subsequent to this hearing both parties, the West Frok of LaBonte and Wagon Mound water users and the Natural Bridge Ranch, inc., expressed satisfaction with the program of the petitioners, namely, rehabilitation of the distribution system of the Downey Park supplemental supply distribution system and stoppage of the large amount of seepage from LaPrele Dam as part of the rehabilitation program.

9. The State Board of Control met in a special meeting on the 3rd of January 1975, at the request of the petitioners. All evidence received at the hearing of 19 November 1974 was available to the Board as well as the transcript of said hearing. Also present were the petitioners and their counsel and the Upper Water Users and their counsel. A reporter was not present and the following is a resume of testimony presented.

a. Mr. Tom Burley, Secretary of the Douglas Reservoirs Water Users Associatior appeared first for the petitioners and summarized the unsuccessful efforts of the Association over the past few years to acquire financing to repair LaPrele Dam. He also explained some of the details of the contractual arrangements with Panhandle Eastern and the Association that had not been brought out at the Douglas hearing. He mentioned that consents to the petition had been received from all members of the Association except four and that those were expected in the near future. (see paragraph 9.)

The Association has started action to form the Douglas Irrigation District in conjunction with the agreement with Panhandle Eastern.

Mr. Burley stated that all concerned, including contestants, had agreed that Section 41-4.1 Wyoming Statutes applies to this petition as far as the change to preferred use is concerned, and read this section to all present. He concluded with a discussion of present versus future uses of water from LaPrele Reservoir and stressed that the Association is convinced that the granting of this petition is essential to the future of the Association.

b. Mr. Houston Williams, attorney for Panhandle Eastern, then covered the objections submitted by the contestants, point by point, and concluded by stating that the only economic impact on Converse County, if the petition is granted, will be favorable.

c. Mr. Patrick Hand, attorney for the contestants holding water rights above LaPrele Reservoir, then outlined the objections of his clients to the petition. The main objection was that historically there has not been any regulation of water above the dam on LaPrele Creek and contestants fear that granting of the petition would make regulation necessary. He discussed possible alternate sources of water which Panhandle Eastern has available to them and he felt these would be sufficient

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b. Mr. Houston Williams, attorney for Panhandle Eastern, then covered the objections submitted by the contestants, point by point, and concluded by stating that the only economic impact on Converse County, if the petition is granted, will be favorable.

c. Mr. Patrick Hand, attorney for the contestants holding water rights above LaPrele Reservoir, then outlined the objections of his clients to the petition. The main objection was that historically there has not been any regulation of water above the dam on LaPrele Creek and contestants fear that granting of the petition would make regulation necessary. He discussed possible alternate sources of water which Panhandle Eastern has available to them and he felt these would be sufficient

to operate a coal gasification plant. Mr. Hand pointed out that the actual location ofthe plant in either Campbell or Converse Counties had not yet been decided and if not located in Converse County would have an adverse effect on that county. He asked the Board what they would do about any non-consenters to the petition. In conclusion Mr. Hand asked the Board to deny the petition while admitting that his clients were not against the rehabilitation of LaPrele Dam, but felt there was an alternate way to accomplish this if Panhandle Eastern would make the effort.

d. Mr. Richard Cross, a member of the Douglas Reservoirs Water Users Association who had consented to the petition, asked for and received permission to speak to the Board. He stated that his consent to the petition was given due to economi considerations as he did not want to see the Association lose 5,000 acre-feet of water. He felt more time should be allowed to see if the Association could get approval from the Wyoming Legislature for an extended loan at low interest, although admitting that many owners under the Association could not afford the repayment cost of such a loan.

e. Mr. Houston Williams, attorney for Panhandle Eastern, pointed out that under the proposed rehabilitation contract Panhandle Eastern would be repaying the loan at a rate of $28.00 per acre per year, noting that agriculture could not support such a rate, but that industry could.

He then clarified the total irrigated acreage under the Douglas Reservoirs Water Users Association as being 10,304.5 acres rather than the 11,236.48 acres as was given at the November 29th hearing at Douglas. Of this total he said consents had been received from all owners except for 738 acres, and again stressed that remaining consents would be obtained in the near future. (Subsequent to this meeting the petitioners furnished consents to the Board covering 737 acres. The one acre of land not covered is in the NW¼NW¼ of Section 34, Township 33 North, Range 73 West. The owner of record has moved from Wyoming and all efforts to locate him have been unsuccessful to date.)

f. The Board reconvened in the afternoon of 3 January 1975 and continued the discussion on all evidence received during the day, recessed, and reconvened on the 4th of January 1975.

g. During the time the Board was considering the evidence, the Board Staff was checking U.S.G.S. water supply records concerning winter flows into LaPrele Reservoir. It was determined and presented to the Board that historically winter storage and carry over storage has been ineffective due to leakage from the reservoir. Further, the records for the periods October 1 through March 31 of each water year, from 1930 to 1970, revealed the range of inflow into LaPrele Reservoir was from 885 acre-feet in 1941 to 5037 acre-feet in 1947, and averaged more than 2,800

to operate a coal gasification plant. Mr. Rand pointed out that the actual location of the plant in either Campbell or Converse Counties had not yet been decided and if not located in Converse County would have an adverse effect on that county. He asked the Board what they would do about any non-consenters to the petition. In conclusion Mr. Rand asked the Board to deny the petition while admitting that his clients were not against the rehabilitation of LaPrele Dam, but felt there was an alternate way to accomplish this if Panhandle Eastern would make the effort.

d. Mr. Richard Cross, a member of the Douglas Reservoirs Water Users Association who had consented to the petition, asked for and received permission to speak to the Board. He stated that his consent to the petition was given due to economic considerations as he did not want to see the Association lose 5,000 acre-feet of water. He felt more time should be allowed to see if the Association could get approval from the Wyoming Legislature for an extended loan at low interest, although admitting that many owners under the Association could not afford the repayment cost of such a loan.

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f. The Board reconvened in the afternoon of 3 January 1975 and continued the discussion on all evidence received during the day, recessed, and reconvened on the 4th of January 1975.

g. During the time the Board was considering the evidence, the Board Staff was checking U.S.G.S. water supply records concerning winter flows into LaPrele Reservoir. It was determined and presented to the Board that historically winter storage and carry over storage had been ineffective due to leakage from the reservoir. Further, the records for the periods October 1 through March 31 of each water year, from 1920 to 1970, revealed the range of inflow into LaPrele Reservoir was from 885 acre-feet in 1961 to 5037 acre-feet in 1947, and averaged more than 2,800

acre-feet per year, or better than 50% of the 5,000 acre-feet contracted for by Panhandl Eastern Pipe Line Company.

h. The Board also considered a Memorandum of Agreement dated December 4, 1974 between the Association and second parties consisting of appropriators of water from West Fork LaBonte Creek and Wagonhound Creek. The Association has water rights on and receives supplemental supplies of water for storage in LaPrele Reservoir from Rocky Fork Creek, Gould Creek and Reed Creek all Tributaries of the West Fork LaBonte Creek. These diversions known as the Downey Park diversions have not been utilized to their maximum due to various circumstances. This Memo sets out certain actions and agreements between both parties, the accomplishment of which will have the end result of increasing the amount of supplemental water available for storage in LaPrele Reservoir from these sources, thereby reducing the demand on LaPrele Creek.

i. At the close of the discussion, a motion made by Superintendent Karl Michael, and seconded by Superintendent Kenneth Bower, was unanimously passed granting the petition subject to the limitations imposed under Section 41-4.1 of the Wyoming Statutes, and it was determined by the Board that the limitations of Section 41-4.1 of the Statutes would be met and that no injury would occur to any other water user if the following actions were taken:

(1) Full utilization of winter storage in LaPrele Reservoir.

(2) Rehabilitation of the Downey Park supplemental supply collection system and full utilization of this source.

(3) After formation of the Douglas Irrigation District, which would replace the Association, the Board recommends rehabilitation of the distribution system below LaPrele Dam. This would result in a savings of water now being lost. The Association has agreed to do that if all else planned is carried out.

CONCLUSIONS OF LAW

The Board unanimously agreed that the Findings of Fact contain the elements necessary to comply with Section 41-4.1 and Section 41-10.4 Wyoming Statutes, and that the petition should be granted subject to certain conditions as contained in the Order.

ORDER

It is hereby ordered that this petition be and the same is GRANTED, without loss of priority and subject to the following conditions.

1. Now water rights on LaPrele Creek, either above or below the LaPrele Dam and Reservoir, in good standing at the time the cange is made shall be injured.

2. It is further ordered that upon completion of the rehabilitation of LaPrele Dam and Reservoir by Panhandle Eastern to a storage capacity of 20,000 acre-feet, that the following permits be amended to show Industrial use as a use in addition to irrigation and domestic.

Permit No. 728 Res., The LaPrele Reservoir

Permit No. 1581 Res., Enl. LaPrele Reservoir

The following listed permits are those which utilize the stored water in LaPrele Reservoir. Since this Order and the agreement between the petitioners referenced herein would reduce the amount of water available for irrigation of lands under these permits, a notation will be annotated to these water rights making reference to this Order.

Permit No. 1430 Enl.)
Permit No. 1670 Enl.)
Permit No. 2968 Enl.) All diverting through the LaPrele Ditch (formerly
Permit No. 4054 Enl.) known as Table Mountain Ditch). Water stored in
Permit No. 4139 Enl.) LaPrele Reservoir.
Permit No. 4530 Enl.)
Permit No. 4589 Enl.)

Permit No. 16786

Permit No. 4055 Enl.)
Permit No. 4531 Enl.) All diverting through the West Side Ditch. Water
Permit No. 4759 Enl.) stored in LaPrele Reservoir.

3. It is further ordered that upon completion of the rehabilitation of LaPrele Dam and when the storage capacity of LaPrele Reservoir has been restored to 20,000 acre-feet, that Panhandle Eastern be authorized to divert stored water from said reservoir in an amount not to exceed 5,000 acre-feet in any given water year. This water will be conveyed from the LaPrele Reservoir down LaPrele Creek to the North Platte River, and down the North Platte River to a point located South 20° 21' East, 5,169 feet from the northwest corner of Section 7, Township 33 North, Range 71 West and situated in Lot 3 of said Section 7. At said point the water will be diverted through the Panhandle Pipeline No. 1 (Permit Nos. 7613 Res. and 7614 Res.) which reservoir is to be located in portions of Sections 5, 6, 7 and 8, Township 33 North, Range 71 West and Section 1, Township 33 North, Range 77 West, and Sections 31 and 36, Township 34 North, Range 72 West, all in

Converse County. There the water may be stored or passed through for industrial purposes in a coal gasification plant to be located at a yet to be selected site and such water may nit be used for any other purposes. When the final site has been selected and prior to utilization of water under this Order, Panhandle Eastern is required to notify the Board of Control of the exact location of said point of use for proper notation in the Board's records.

The 5,000 acre-feet authorized for industrial use by Panhandle Eastern will be released from LaPrele Reservoir in the manner set forth in the May 28, 1974 Agreement between the Douglas Reservoirs Water Users Association and Panhandle Eastern Pipe Line Company. This agreement divides the water year into two periods as follows.

1. For the period beginning on October 1 and continuing through April 30 of the next succeeding year (the winter season), the Association will deliver Panhandle Eastern water as available up to 2,500 acre-feet on such reasonably uniform basis as may be scheduled by Panhandle Eastern.

2. For the period from May 1 through September 30 (the irrigation season) , the Association will deliver to Panhandle Eastern, on a reasonably uniform basis as set by schedule submitted by Panhandle Eastern, the difference between actual deliveries during the immediately preceding winter season and 5,000 acre-feet. In the event there is insufficient water impounded in the reservoir to satisfy both the Association's needs and Panhandle's contract, during any irrigation season, ten the available water shall be apportioned three-fourths to the Association and one-fourth to Panhandle. Such apportionment shall apply only to available water during the irrigation season and not to the amounts to be delivered to Panhandle during any winter season.

It is further ordered that if present dam leakage is not stopped as a result of the rehabilitation project, the amount of water discharged through such leak, computed in cubic feet per second, shall be accounted for as storage water and charged and delivered to Panhandle Eastern as a portion of their 5,000 acre-feet entitlement.

It is further ordered that all measuring devices and gagin stations dddmed necessary and essential for the administration of water to move through the system will be installed at the petitioner's expense. The State Engineer and Superintendent of Water Division One shall determine the necessity and location of such measuring devices and gaging stations; and the installation of same shall be accomplished to the satisfaction of the Superintendent of Division One.

The storage right for the one acre of land located in the $NW\frac{1}{4}NW\frac{1}{4}$ of Section 34, Township 33 North, Range 73 West for which consent to the petition from the owner of record was not received, will continue to receive the same benefits and be subject to the same liabilities as existed prior to the signing of the subject Agreement. If said owner should consent he will be subject to all conditions contained in said agreement and this Order.

It is evident that imposition of this project on LaPrele Creek will result in a considerable increase in water administration costs to Converse County. Since the benefits derived from this additional administration accrue mainly to the co-petitioner Panhandle Eastern, said co-petitioner should supplement the budget of Converse County to the extent of any such increased costs, as determined by the Superintendent and State Engineer, if co-petitioner Panhandle's coal gasification plant is not finally located entirely within Converse County.

It is further ordered that all water delivered to Panhandle Eastern by the Association shall be deducted from the annual entitlement of water for LaPrele Reservoir.

It is further ordered that conveyance losses of water in transit from the Downey Park supplemental diversion system, to LaPrele Reservoir, and conveyance losses from the LaPrele Dam to co-petitioner Panhandle Eastern's proposed point of diversion on the North Platte River shall be determined by the Superintendent of Water Division One and the Hydrographer-Commissioner in charge and proper allowance for same shall be considered in administering the appropriations affected.

DONE AT CHEYENNE, COUNTY OF LARAMIE, STATE OF WYOMING, THIS 3RD DAY OF JANUARY, 1975.

STATE BOARD OF CONTROL

/s/
George L. Christopulos, President

ATTEST:

/S/
William Long, Ex-Officio Secretary

ENTERED: May 19, 1975

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APPENDIX B

APPENDIX B

TESTING OF MORTONS WELL NO. 1-23

An estimate of the transmissivity and hydraulic conductivity of the Lance and Fox Hills formations was obtained by analyzing data from a long-term pump test of Mortons Well No. 1-23. Mortons Well No. 1-23 is located 13 miles north of Douglas, Wyoming and is completed to a depth of 6,330 feet. The well is open from a depth of 4,154 to 6,330 feet through screened intervals which consist of about 18 percent of the open interval. The well is completed in the Lance Formation and the upper part of the Fox Hills Formation.

During February and March 1981, a long-term pumping test was conducted on Mortons Well No. 1-23 for 31 days at an average pumping rate of 219 gallons per minute (gpm).* Water levels were monitored in the Mortons Well during and after pumping. During the first 100 minutes of testing, the pumping rate was somewhat higher than the average pumping rate. The average pumping rate for the total test was lower than the apparent average (233 gpm) because the pump was off for a total of about 20 to 22 hours. These variations in pumping rate do not appear to adversely affect the analysis applied here.

Figure B-1 is a semi-logarithmic plot of drawdown versus time for the test of Mortons Well No. 1-23. The Jacob straight-line (1940) method is applied to the data up to where time (t) is about 5,000 minutes. A transmissivity value of 580 gpd/ft (78 ft^2/day) has been calculated based on the plot. If the aquifer thickness is assumed to be the interval of the open well, then the hydraulic conductivity can be

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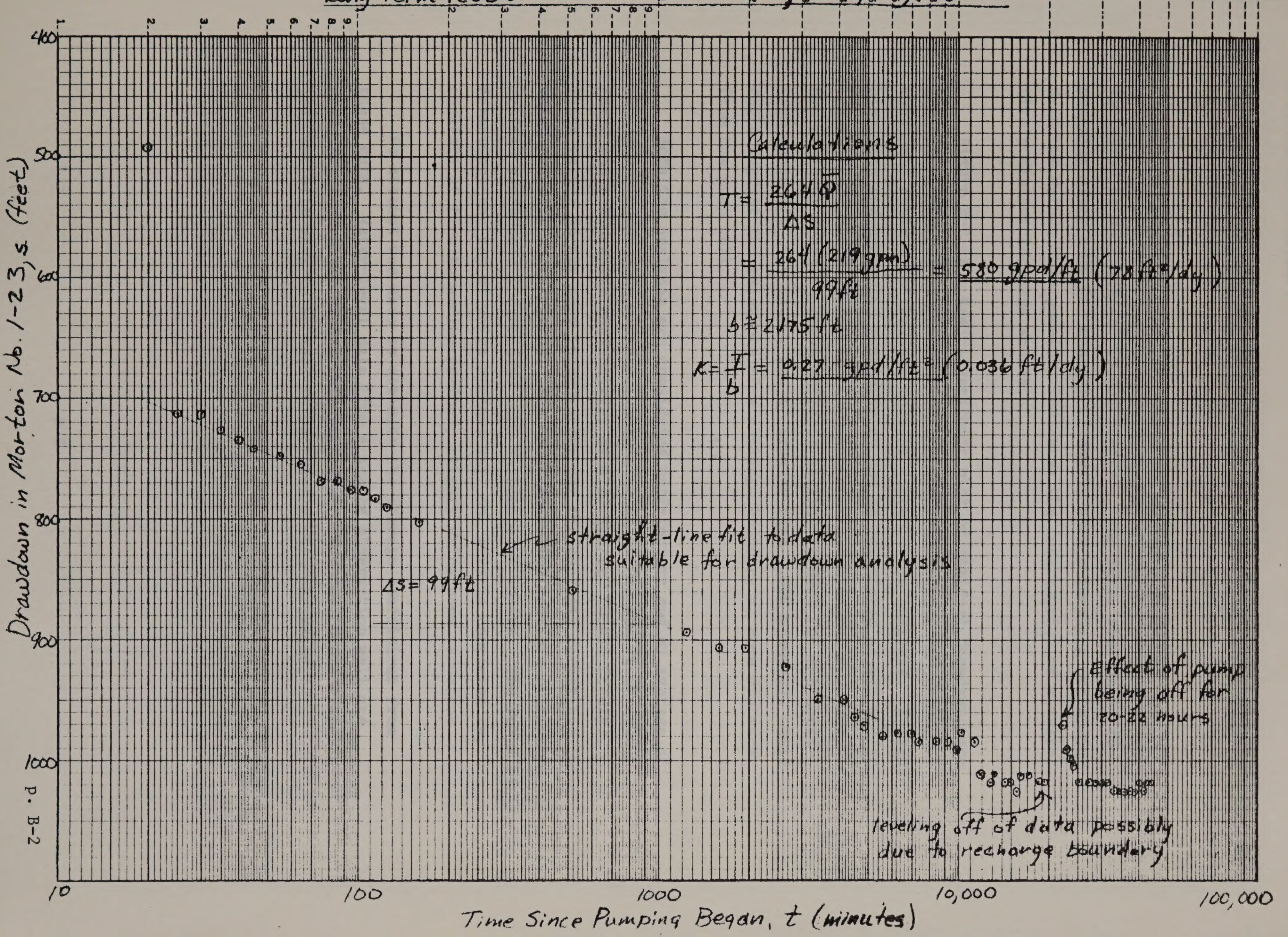
*For source of data see data see references.

K+E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS KEUFFEL & ESSER CO. MADE IN U.S.A. 46 6013

6-9-81

Long-Term Test of Morton No. 1-23 Well, Pumping Portion



estimated at 0.27 gpd/ft^2 (0.036 ft/day). The later time data, especially after t=10,000 minutes (7 days), show a leveling off of the drawdown data. This possibly indicates the interception of a relatively distant recharge source.

Figure B-2 is a semi-logarithmic plot of residual drawdown versus t/t^1. The straight-line recovery analysis (Cooper and Jacob, 1946) was applied to the data thought suitable for analysis. A transmissivity and hydraulic conductivity can be calculated as 420 gpd/ft (56 ft^2/day) and 0.19 gpd/ft^2 (0.026 ft/day), respectively. Note that the residual drawdown curve deflects slightly upward for the condition where t/t' <10 (i.e., for t' greater than 5,000 minutes). This could suggest the existence of a recharge boundary at some distance from the pump well.

Both the analyses are considered satisfactory and an average of the values calculated gives a transmissivity of 500 gpd/ft (67 ft^2/day) and a hydraulic conductivity of 0.23 gpd/ft^2 (0.031 ft/day). These values do not seem inconsistent for the geologic formations in which the well was screened. The Lance Formation consists of fine-grained sandstones interbedded with carbonaceous shales. The Fox Hill Formation, the top of which Mortons Well No. 1-23 is completed in, consists of fine to medium grained, slighty calcareous sandstone.

No attempt was made to estimate the storage coefficient from these data. Water-level data from a nearby observation well are needed to accurately assess this parameter. For now, professional judgment will have to be used in estimating this parameter.

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KEUFFEL & ESSER CO. MADE IN U.S.A.

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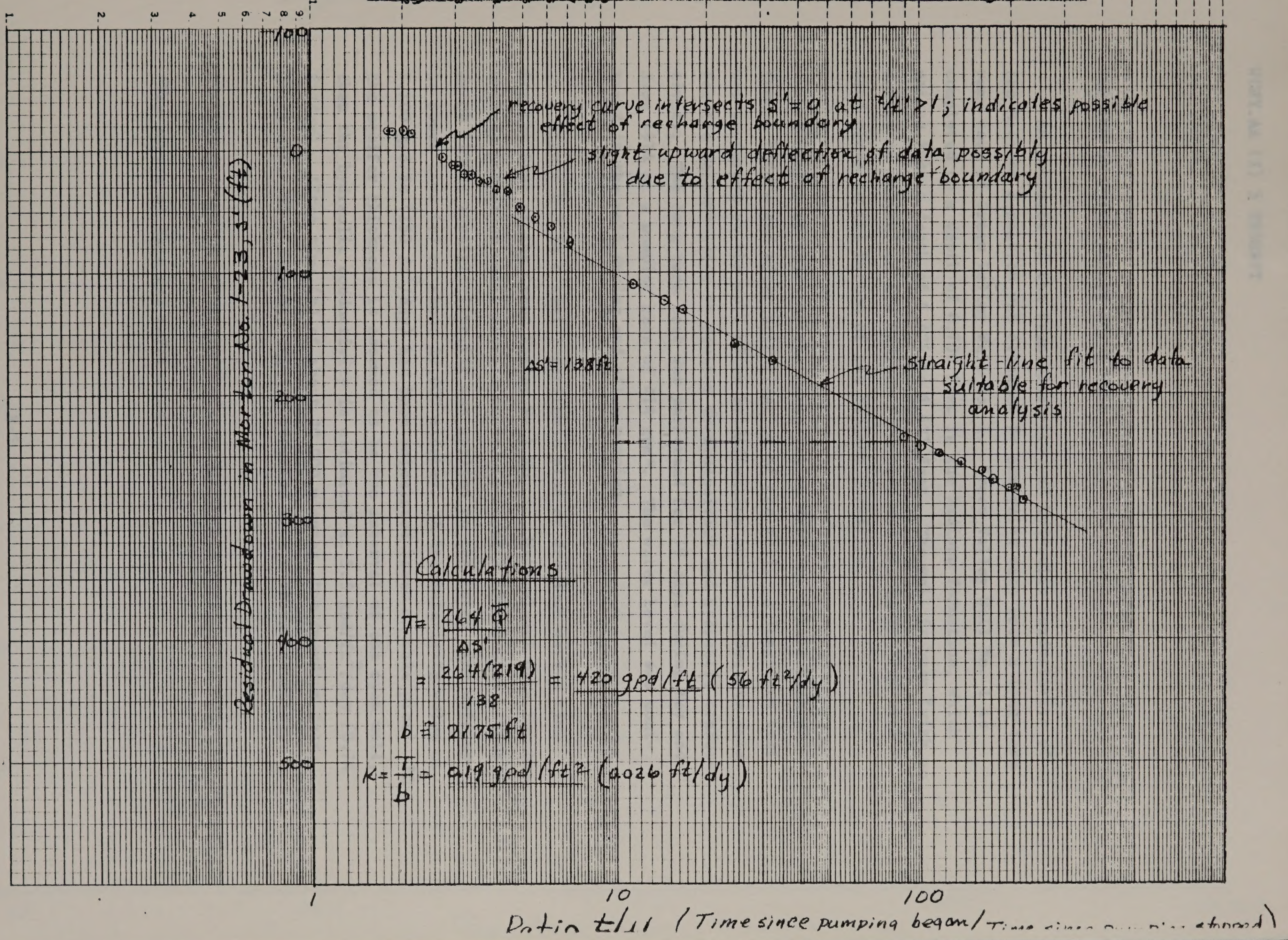
Long-Term Test of Morton No. 1-23 Well, Recovery Portion



TESTING OF GREEN VALLEY NO. 1 WELL

An estimate of the transmissivity and hydraulic conductivity of the Madison Formation was obtained by analyzing data from a long-term pump test of Green Valley Well No. 1. Green Valley Well No. 1 is completed to a depth of 6,700 feet in the Madison Formation, which exists from a depth of 6,426 to 6,627 feet. The well is open (with no screen or casing) to the Madison Formation and was backfilled with sand close to the bottom of the Madison Formation.

A number of tests of the Green Valley Well No. 1 have been performed before and after acidification of the well. A long-term test was performed on the well after acidification produced adequate data for the determination of aquifer transmissivity and hydraulic conductivity. The long-term test was performed for 19 days during May and June 1974 at a pumping rate of 414 gpm*. The water level was monitored in the well during and after pumping.

Figure B-3 is a semi-logarithmic plot of drawdown versus time for the test of the Green Valley Well No. 1. Water-level data for the well do not exist until after time (t) is about 3,000 minutes. Thus a Jacob (1940) straight-line fit was applied to the later time data up to about time (t) of about 20,000 minutes. A transmissivity value of 1,100 gpd/ft (150 ft^2/day) has been calculated based on this plot. If the aquifer thickness is assumed to be the interval of the open well, then the hydraulic conductivity is estimated at 5.5 gpd/ft^2/day (0.74 ft/day). After time (t) of about 20,000 minutes, the drawdown data level off. This suggests the interception of a recharge boundary.

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*For source of data see references.

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Figure ~~A-3~~ B-3

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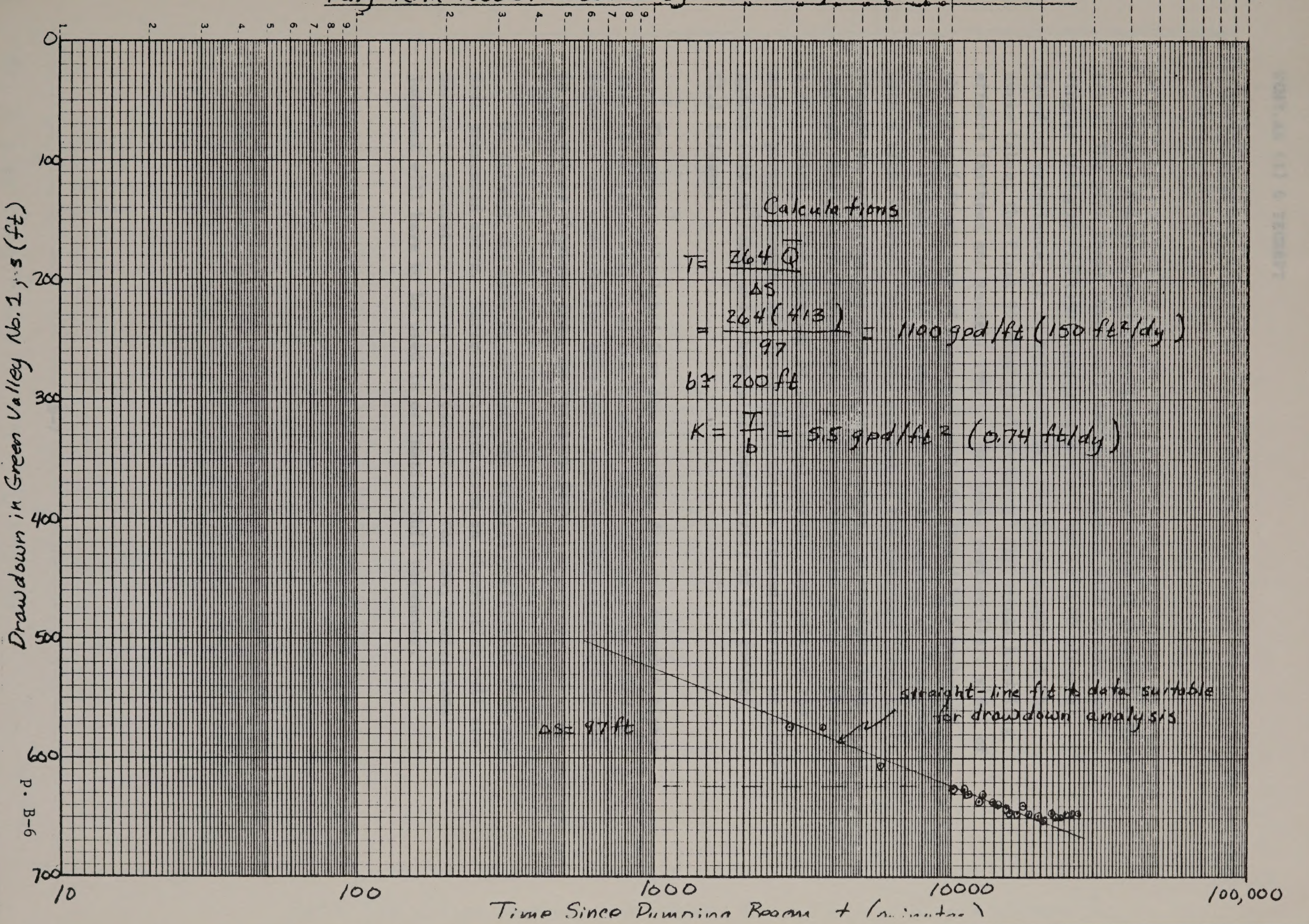
Long-Term Test of Green Valley No. 1 Well, Pumping Portion



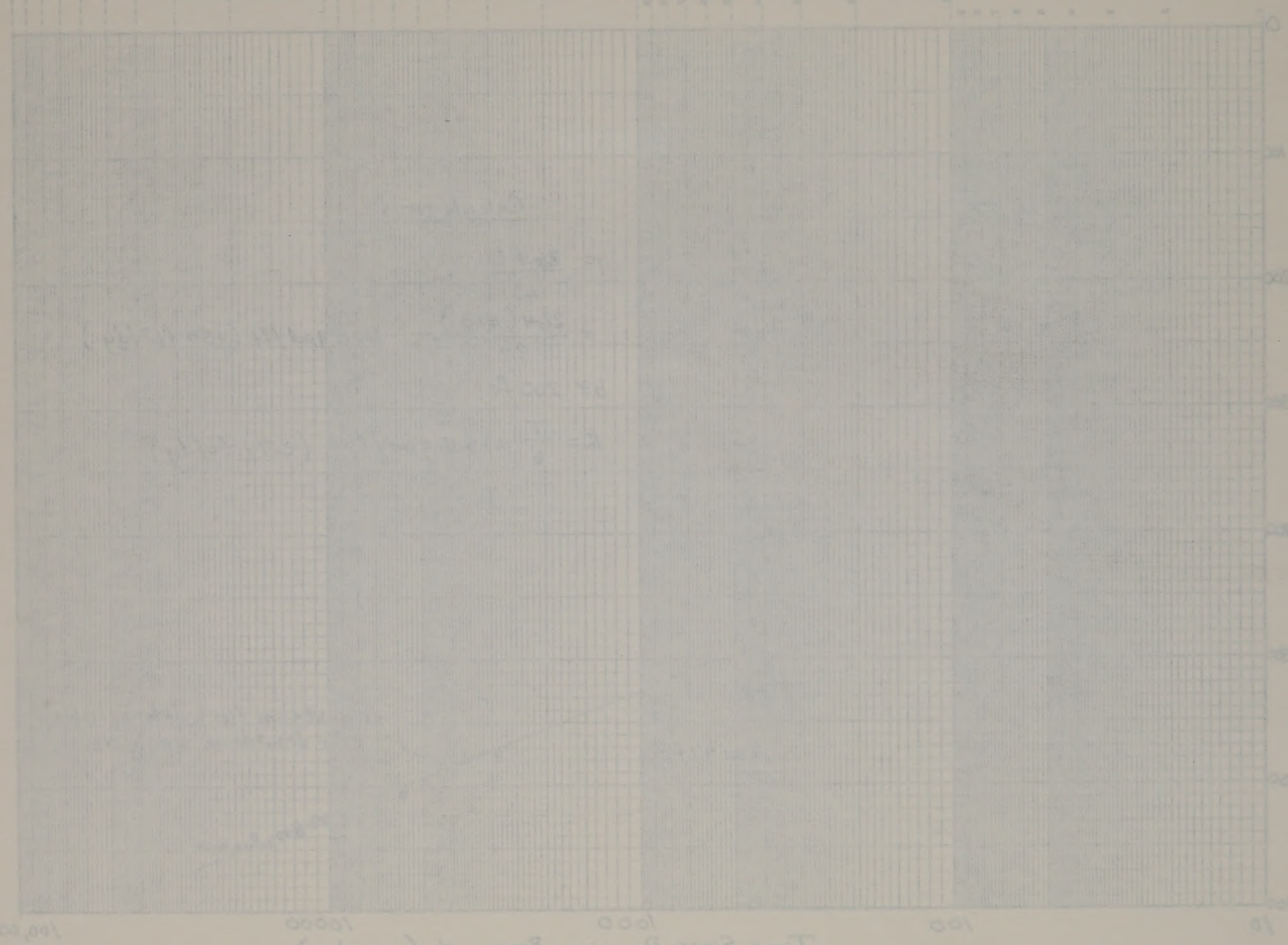

Long-Term Test of Green Valley No. 1 Well, Pumping Portion

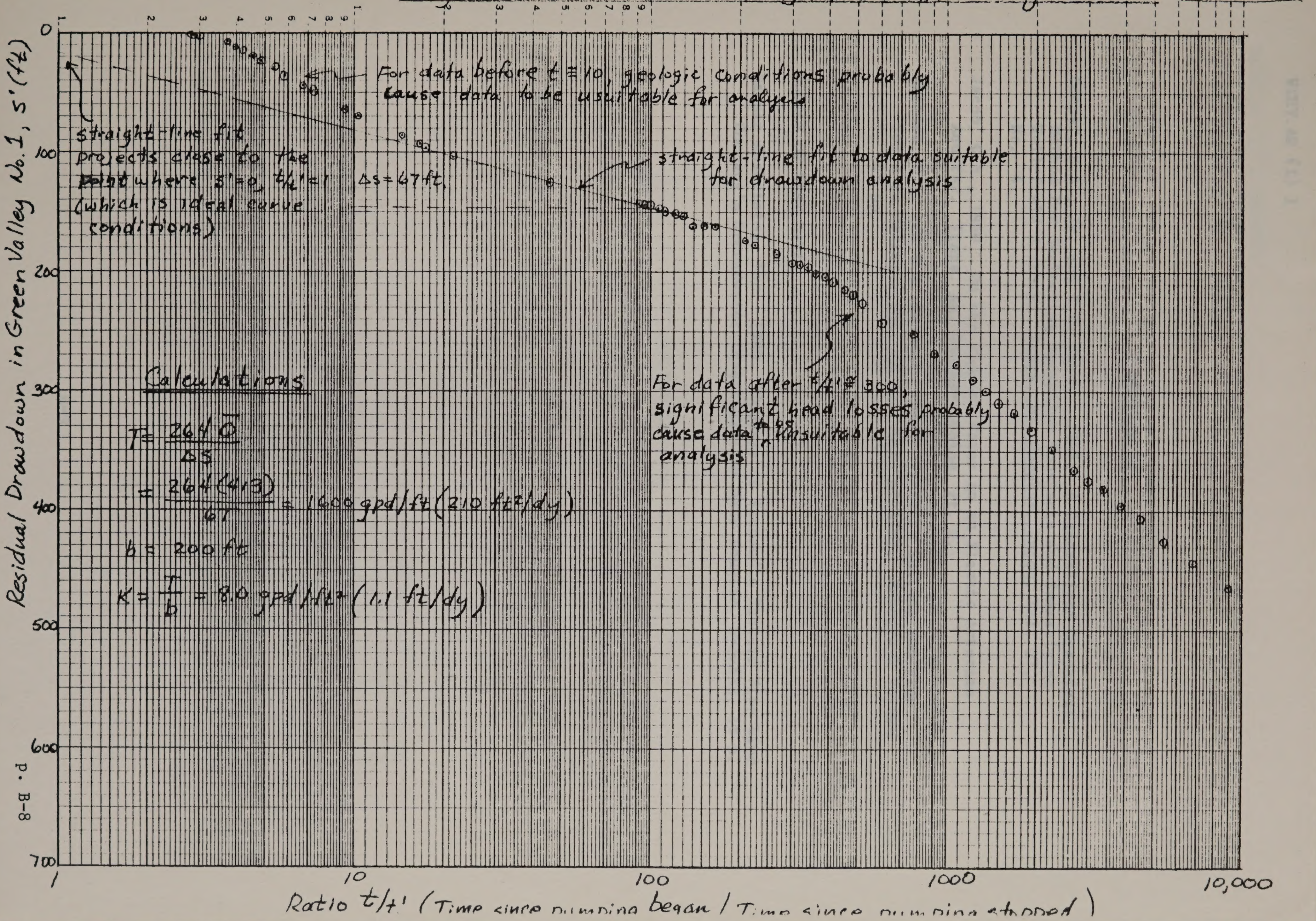
Figure B-4 is a semi-logarithmic plot of residual drawdown versus t/t'. The plot shows three well defined segments with breaks occurring at t/t' $\cong$ 20 (t $\cong$ 1350 minutes) and t/t' $\cong$ 300 (t' $\cong$ 90 minutes). Based on experience, it is believed that the first segment of the curve (about the first 90 minutes of recovery) represents head loss effects (Mathews and Russell 1967). The later portion (left side) of the curve (after 1 day of recovery) could be caused by a number of effects: a fault, nearby boundary, stratified layers, or fractures with a tight matrix. The middle portion of the recovery curve is thought to represent the true aquifer response. A straight line through this portion comes close to intercepting the point (t'/t = 1, s'=0), which is the behavior of the ideal curve. Analysis of the middle portion (Cooper and Jacob 1946) gives a transmissivity of 1,600 gpd/ft (210 ft^2/day) and a hydraulic conductivity of 8.0 gpd/ft^2 (1.1 ft/day).

The values calculated from the recovery data are somewhat higher than those calculated from the drawdown data. Because the drawdown record is not complete for this test, more credibility should be put in the values obtained from the recovery data.

No attempt was made to estimate the storage coefficient from the data presented above. Water-level data from an observation well are needed to accurately assess this parameter. For now, professional judgment will have to be used in estimating this parameter.

Figure B-4

Long-Term Test of Green Valley No. 1 Well, Recovery Portion



REFERENCES

Cooper, H.S., Jr. and C.E. Jacob. 1946. A Generalized Graphical Method For Evaluating Formation Constants and Summarizing Well-field History: Trans. Am. Geophys. Union, Vol. 27, No. 4.

Jacob, C.E., 1940. On the Flow of Water in an Elastic Artesian Aquifer. Trans. Am. Geophys. Union, Pt. 2.

Mathews, C.S. and D.G. Russell. 1967. Pressure Buildup and Flow Tests in Wells: Soc. of Pet. Eng. of AIME, Monograph Volume 1, 145 pp.

SOURCE OF TEST DATA

Banner Associates, Inc. 1980. Summary of Panhandle Eastern Pipe Line Company's Groundwater Investigations Near Douglas, Wyoming, 18 p.

APPENDIX C

APPENDIX C

An operations model of the WyCoalGas water supply system was constructed by Banner Associates (1981). The model calculates the quantity of water available to WyCoalGas from surface water sources, and allocates water to the gasification plant based on the following priorities:

(1) seepage from LaPrele Dam, which by Board of Control Order No. 20 is charged to WyCoalGas,

(2) North Platte direct diversion water,

(3) releases from LaPrele Reservoir,

(4) water from Combs Reservoir,

(5) ground water from the South Well Field, up to a maximum rate of 5.5 acre-feet per day,

(6) ground water from the North Well Field.

The model was used to calculate how the WyCoalGas water supply system could be operated during a 50-year period with climatic and runoff conditions identical to those in the period 1930 to 1979, surface water demands as they existed in 1980, and LaPrele Reservoir operated according to the Wyoming Board of Control Order No. 20. North Platte River surplus water is calculated from the North Platte River operations model (Table 5-5). A variation on the model was used to calculate historical flows in LaPrele Creek at its mouth, historical diversions, and consumptive use by the Douglas Reservoirs Water Users Association.

A sample output from the model is shown in Table C-1. Each of the items in Table C-1 is explained in Table C-2, and the algorithms used are listed in Table C-3. The basic data for the operations model are presented in Table C-4.

Table C-1.

WYCOALGAS, INC.
WATER SUPPLY OPERATION STUDY
BANNER JOB # 1803-3

LAPRELE RESERVOIR INITIALLY AT DEAD POOL (15 AC-FT)
PANHANDLE RESERVOIR #1 INITIALLY AT 13,270 AC-FT
N. PLATTE SUPPLY 'CUSHION' 6,000 AC-FT
GROUNDWATER SUPPLY MAXIMUM 4,000 AC-FT/YR.
CONVEYANCE LOSS FOR LAPRELE SUPPLY 10%

SUMMARY- 50 YEARS OF OPERATION	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	YEAR
LAPRELE RESERVOIR													
1 RESERVOIR INFLOW	0.40	0.43	0.44	0.42	0.42	0.91	5.62	14.23	4.39	0.70	0.23	0.23	28.42
2 SENIOR RIGHTS DEMAND	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.12	1.08	1.12	1.12	1.08	5.53
2.1 ASSOC. RETURN FLOWS	0.10	0.08	0.06	0.05	0.05	0.04	0.05	0.09	0.12	0.20	0.22	0.19	1.25
3 SENIOR RIGHTS BYPASS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.03	0.81	0.35	0.06	0.08	2.33
ASSOCIATION DEMAND (INCLUDING CARRIER RIGHTS)													
4 TOTAL DEMAND	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.83	5.55	9.79	8.81	7.18	34.17
5 DIRECT FLOW BYPASS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.62	2.48	0.34	0.17	0.15	5.77
6 STORAGE RELEASES	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	2.45	5.73	1.41	0.00	9.72
7 DEFICIT	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.61	3.71	7.23	7.03	18.67
WYCOALGAS SUPPLY													
8 SEEPAGE (STORAGE ACCT.)	0.01	0.02	0.02	0.03	0.03	0.08	0.21	0.40	0.41	0.26	0.11	0.03	1.61
9 STORAGE RELEASE	0.31	0.38	0.38	0.29	0.17	0.23	0.04	0.16	0.12	0.25	0.23	0.25	2.81
RESERVOIR CONDITIONS													
10 ADD TO STORAGE	0.40	0.43	0.44	0.42	0.42	0.91	5.62	5.80	0.13	0.00	0.00	0.00	14.57
A ASSOCIATION	0.00	0.00	0.02	0.04	0.12	0.39	4.16	5.15	0.13	0.00	0.00	0.00	10.01
B WYCOALGAS	0.40	0.43	0.42	0.38	0.30	0.52	1.46	0.65	0.00	0.00	0.00	0.00	4.56
11 TOTAL STORAGE RELEASE	0.32	0.40	0.41	0.32	0.20	0.31	0.26	0.69	2.98	6.24	1.74	0.27	14.14
12 SPILLS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.78	0.97	0.00	0.00	0.00	5.75
13 EVAPORATION	0.00	0.00	0.00	0.00	0.00	0.01	0.04	0.11	0.13	0.10	0.03	0.00	0.42
A ASSOCIATION	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.09	0.10	0.05	0.00	0.00	0.28
B WYCOALGAS	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.02	0.03	0.05	0.03	0.00	0.14
14 CHANGE IN STORAGE	0.08	0.03	0.03	0.10	0.22	0.59	5.32	5.00	-2.98	-6.34	-1.77	-0.28	-0.00
A ASSOCIATION	0.00	0.00	0.02	0.04	0.12	0.39	4.13	4.93	-2.43	-5.79	-1.41	0.00	-0.00
B WYCOALGAS	0.08	0.03	0.02	0.06	0.09	0.21	1.19	0.08	-0.56	-0.55	-0.36	-0.28	-0.00
15 EOM STORAGE	0.09	0.12	0.15	0.25	0.47	1.06	6.38	11.38	8.40	2.06	0.29	0.01	(19.53)
A ASSOCIATION	0.00	0.00	0.02	0.06	0.18	0.57	4.69	9.62	7.19	1.41	0.00	0.00	.
B WYCOALGAS	0.09	0.12	0.14	0.19	0.29	0.49	1.68	1.76	1.20	0.65	0.29	0.01	.
C ELEVATION (FT)	5388.9	5390.3	5391.7	5395.8	5403.3	5417.6	5456.7	5468.9	5454.1	5424.0	5402.6	5379.6	.
D SURFACE AREA (ACRES)	7.6	9.4	11.1	17.5	30.3	64.1	273.6	406.6	310.7	106.4	19.4	1.9	.
15.1 LAPRELE CREEK AT MOUTH	0.42	0.48	0.47	0.37	0.25	0.35	0.31	5.88	1.94	0.77	0.47	0.40	12.11
PANHANDLE RESERVOIR #1													
LAPRELE SUPPLY													
16 WYCOALGAS'S LAPRELE SUPPLY	0.32	0.40	0.41	0.32	0.20	0.31	0.26	0.56	0.53	0.51	0.34	0.27	4.42
17 CONVEYANCE LOSS	0.03	0.04	0.04	0.03	0.02	0.03	0.03	0.06	0.05	0.05	0.03	0.03	0.44
18 NET LAPRELE SUPPLY AVAILABLE	0.29	0.36	0.37	0.29	0.18	0.28	0.23	0.50	0.48	0.46	0.30	0.25	3.98
A DIRECT DIVERSION TO PLANT	0.29	0.36	0.37	0.29	0.18	0.28	0.23	0.50	0.47	0.46	0.30	0.22	3.94
B AVAILABLE FOR STORAGE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.03	0.04
C BYPASS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

C-3

 (CONTINUED ON FOLLOWING PAGE)

Table C-1 (concluded).

WYCOALGAS, INC.
WATER SUPPLY OPERATION STUDY
BANNER JOB # 1803-3

LAPRELE RESERVOIR INITIALLY AT DEAD POOL (15 AC-FT)
PANHANDLE RESERVOIR #1 INITIALLY AT 13,270 AC-FT
N. PLATTE SUPPLY 'CUSHION' 6,000 AC-FT
GROUNDWATER SUPPLY MAXIMUM 4,000 AC-FT/YR.
CONVEYANCE LOSS FOR LAPRELE SUPPLY 10%

SUMMARY- 50 YEARS OF OPERATION	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	YEAR
1974 N. PLATTE RIVER SUPPLY													
19 O=T=R WATER	0.00	0.00	0.35	1.42	3.02	0.26	10.53	58.79	50.15	0.00	0.00	0.00	124.52
20 WATER AVAILABLE TO PANHANDLE	0.00	0.00	0.10	0.42	1.12	0.08	2.72	3.94	3.20	0.00	0.00	0.00	11.60
A DIRECT DIVERSION TO PLANT	0.00	0.00	0.01	0.04	0.06	0.01	0.07	0.03	0.02	0.00	0.00	0.00	0.24
B TO RESERVOIR STORAGE	0.00	0.00	0.07	0.12	0.40	0.00	1.01	1.34	0.42	0.00	0.00	0.00	3.35
C BYPASS	0.00	0.00	0.02	0.26	0.66	0.08	1.64	2.58	2.76	0.00	0.00	0.00	8.00
D TOTAL WATER USED	0.00	0.00	0.08	0.16	0.46	0.01	1.08	1.37	0.44	0.00	0.00	0.00	3.59
RESERVOIR CONDITIONS													
21 ADD TO STORAGE	0.00	0.00	0.07	0.12	0.40	0.00	1.01	1.34	0.42	0.00	0.00	0.03	3.39
A LAPRELE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.03	0.04
B N. PLATTE	0.00	0.00	0.07	0.12	0.40	0.00	1.01	1.34	0.42	0.00	0.00	0.00	3.35
22 STORAGE RELEASES	0.12	0.13	0.13	0.18	0.21	0.23	0.19	0.00	0.02	0.06	0.21	0.17	1.66
A LAPRELE	0.01	0.01	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.05
B N. PLATTE	0.11	0.13	0.13	0.17	0.20	0.22	0.19	0.00	0.02	0.06	0.20	0.17	1.61
23 EVAPORATION	0.10	0.06	0.05	0.05	0.04	0.08	0.13	0.19	0.22	0.27	0.24	0.15	1.56
A LAPRELE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
B N. PLATTE	0.10	0.06	0.05	0.05	0.04	0.08	0.13	0.19	0.22	0.26	0.24	0.15	1.56
25 CHANGE IN STORAGE	-0.22	-0.19	-0.11	-0.11	0.14	-0.31	0.69	1.15	0.19	-0.32	-0.44	-0.29	0.17
A LAPRELE	-0.01	-0.01	0.00	-0.01	-0.00	-0.01	0.00	0.00	0.01	0.00	-0.01	0.03	-0.01
B N. PLATTE	-0.20	-0.18	-0.11	-0.10	0.15	-0.30	0.69	1.15	0.18	-0.32	-0.44	-0.32	0.18
26 EOM STORAGE	15.32	15.13	15.01	14.90	15.04	14.74	15.42	16.58	16.76	16.44	16.00	15.70	.
A LAPRELE	0.03	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.03	.
B N. PLATTE	15.29	15.10	14.99	14.89	15.03	14.74	15.42	16.57	16.75	16.43	15.99	15.67	(10.67)
C ELEVATION (FT)	4938.5	4938.1	4937.8	4937.4	4937.3	4936.6	4938.0	4941.3	4941.4	4940.8	4939.9	4939.2	
D SURFACE AREA (ACRES)	562.4	556.8	553.1	549.0	551.9	542.9	561.9	599.0	603.4	594.4	581.8	573.3	.
GROUNDWATER SUPPLY													
27 GROUNDWATER SUPPLIED TO PLANT	0.01	0.02	0.02	0.02	0.02	0.01	0.02	0.00	0.00	0.02	0.02	0.02	0.18
A GREEN VALLEY	0.01	0.02	0.02	0.02	0.02	0.01	0.02	0.00	0.00	0.01	0.01	0.01	0.16
B MORTON	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.02
COAL GASIFICATION PLANT													
28 PLANT DEMAND	0.42	0.51	0.53	0.53	0.48	0.53	0.51	0.53	0.51	0.53	0.53	0.41	6.02
29 TOTAL PLANT DELIVERIES	0.42	0.51	0.53	0.53	0.48	0.53	0.51	0.53	0.51	0.53	0.53	0.41	6.02
30 PLANT DEFICITS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL WATER CONSUMPTION IN SYSTEM													
31 LAPRELE ASSOCIATION	-0.60	-0.45	-0.36	-0.26	-0.18	0.16	3.86	7.24	1.87	-0.85	-1.16	-0.96	8.30
32 WYCOALGAS	0.37	0.39	0.46	0.50	0.74	0.49	2.51	1.96	0.39	-0.05	-0.03	-0.03	7.72

TABLE C-2

WYCOALGAS WATER SUPPLY OPERATION STUDY
EXPLANATION OF TABULATED OUTPUT

1. Reservoir Inflow
Inflow to LaPrele Reservoir was based on USGS gage #06-6490 records. A multiplication factor of 1.054 was used to account for ungaged contributing drainage.[1]

2. Senior Rights Demand
Senior appropriators' rights along LaPrele Creek downstream of LaPrele Reservoir. The demand was based on 1 cfs per 70 acres during the irrigation season (May through September). 1276 acres = 36.16 $\frac{\text{Ac-Ft}}{\text{Day}}$.

2.1 Association Return Flows
Return flows to LaPrele Creek resulting from irrigation deliveries to LaPrele Association lands. The USBR report[1] on the LaPrele Unit showed return flow studies that indicate 8% of the annual diversions of the Association return to LaPrele Creek and are usable by senior downstream irrigators. The USBR studies also showed total return flows of 48% of annual diversions. For calculation purposes, October through May return flows were based on the previous water year's total diversions times a monthly distribution factor. June through September return flows were based on year-to-date total diversions times a monthly distribution factor (see Appendix A).

3. Senior Rights Bypass
This reflects water bypassed to meet senior downstream direct flow rights. The amount bypassed was the lesser of the reservoir inflow or the senior rights demand; this figure was then reduced by any return flows available for diversion.

4. Association Total Demand
The total demand was based on the optimum water necessary for irrigation requirements. Average monthly values were used based on the 1969 USBR report. The report calculated consumptive use requirements and then applied canal efficiencies of 65%, and farm efficiencies of 65%. The lands irrigated included the Association Lands (10,304.5 acres) as well as the carrier rights (1,149.5 acres) served by Association canals but not part of the Association. The total demand was then reduced by 5% for the demand being met by return flows within the unit itself (see Appendix A).[1]

5. Direct Flow Bypass
The Association Lands and the carrier rights have a direct flow rights amounting to 1 cfs per 70 acres, or a total of 324.55 $\frac{\text{Ac-Ft}}{\text{Day}}$. The amount bypassed was any remaining flows available after meeting senior rights, limited to the lesser of the total demand or the direct flow rights.

6. Storage Releases
LaPrele storage releases were from the Association's account to meet any irrigation demand not met by direct flow.

7. Deficit
Amount of Association's irrigation demand (including carrier rights) that could not be met by direct flow rights or storage releases.

1. The numbers correspond to items listed in Table 1.

8. Seepage
In accordance with the LaPrele agreement, reservoir seepage must be charged against WyCoalGas's storage account and delivered as part of WyCoalGas supply. The seepage was based on an initial estimate of the average monthly capacity of LaPrele Reservoir. A curve of seepage vs. capacity was used which was based on seepage information gathered since the LaPrele Dam rehabilitation (see Appendix A).

9. Storage Release
These were releases made from the WyCoalGas storage account above the seepage release. Storage releases were made to meet any WyCoalGas plant demands not met by seepage or by the WyCoalGas 1974 priority N. Platte right. If storage releases were required, the storage releases were increased to compensate for conveyance losses. In accordance with the LaPrele Agreement, total releases for the period of October-April cannot exceed 2,500 Ac-Ft. Due to this, total year-to-date releases plus the present month's storage release were not allowed to exceed 2,000 Ac-Ft to compensate for the uncontrolled seepage releases in future months that could cause the 2,500 Ac-Ft limit to be exceeded. Similarly, for the period of May through August, year-to-date releases were held to 4,500 Ac-Ft so as not to exceed the yearly 5,000 Ac-Ft limit. Any storage remaining in the WyCoalGas account in September was released in its entirety.

10. Add to Storage
The amount of water placed in storage was the inflow available after the direct flow rights were satisfied but restricted to the one-fill limitation. The storage was separated into two accounts: A) Association; B) WyCoalGas. During the nonirrigation season (Oct-April), all flows were placed in the WyCoalGas account up to 2,500 Ac-Ft. Above the amount, 25% of available flows up to a total maximum of 5,000 Ac-Ft in any year was placed in the WyCoalGas account. All remaining flows were placed in the Association account. Twenty-five percent of any available flows during the irrigation season were placed in the WyCoalGas account limited to the yearly total of 5,000 Ac-Ft with the remaining flows going to the Association account.

11. Total Storage Release
The total storage release includes storage releases for irrigation, storage releases for WyCoalGas, and seepage releases.

12. Spills
Spill will usually occur due to the one-fill limit being reached but can also occur due to the physical capacity of LaPrele Reservoir being exceeded.

13. Evaporation
The evaporation for the month was calculated by averaging the beginning and end-of-month storage in order to determine the average monthly storage. From this, the average surface area was determined and the appropriate evaporation rate applied to that surface area (refer to Appendix A). The losses were distributed between the accounts by a ratio of that account's storage to the total storage.

14. Change in Storage
The monthly storage change was calculated by subtracting storage releases and evaporation losses for each account from the amount added to storage for that account.

15. EOM Storage
The End-of-Month storage was the sum of the previous month's EOM storage plus the present month's change in storage. Each of the accounts was handled in a similar manner. The water surface elevation and the water surface area were based on the total LaPrele Reservoir EOM storage.

15.1 LaPrele Creek at Mouth
The projected flows of LaPrele Creek at its mouth reflect only the flows resulting from LaPrele Dam releases and irrigation return flows. The flows do not include any contributing drainage area below LaPrele Dam. During the nonirrigation season, this included total WyCoalGas releases, spills, and return flows to LaPrele Creek from the Association lands. During the irrigation season, it was assumed that all return flows to LaPrele Creek from the Association lands are utilized by senior downstream irrigators. Thus, the flows during the irrigation season consisted of total WyCoalGas releases, any spills, and return flows from the senior downstream irrigators (assumed to be 48%).

16. WyCoalGas LaPrele Supply
This is the total available to WyCoalGas from the LaPrele Reservoir below LaPrele Dam. This includes seepage plus storage releases from the WyCoalGas account.

17. Conveyance Loss
This is the conveyance loss between LaPrele Dam and WyCoalGas's point of diversion on the North Platte River, assumed to be 10% of the amount available below the LaPrele Dam.

18. Net LePrele Supply Available
The LePrele supply available at WyCoalGas's point of diversion on the North Platte River. This supply was handled either by A) Direct Diversion to Plant; B) Placement in storage in Panhandle Reservoir #1; or C) Bypass. The LePrele supply was first made available to meet the coal gasification plant demand with any excess going to storage. If the storage capacity of Panhandle Reservoir #1 had been reached, any excess was bypassed at the point of diversion.

19. O-T-R Water
The Owed-To-River water quantities were obtained from the "North Platte River Operational Study" performed by WRRI. These are the excess flows in the North Platte System above all ownership and irrigation requirements.

20. Water Available to Panhandle
WyCoalGas has a right to the North Platte O-T-R water of up to 201.2 cfs under a 1974 priority. To assure that no prior rights on the North Platte are harmed, it was assumed that no North Platte water was available to WyCoalGas unless the O-T-R water exceeded 6,000 Ac-Ft in any month. This supply was handled either by: A) Direct diversion to the plant; B) Placement in storage in Panhandle Reservoir #1; C) Bypass. The North Platte supply was first used to meet any plant demand not previously met with any excess going to storage. Water was bypassed if the one-fill limitation

20. Water Available to Panhandle Cont.
had been reached on the N. Platte supply in regard to Panhandle Reservoir #1, if the physical capacity of the Reservoir had been reached, or if limitations due to pipeline capacity existed. Column 20D tabulates the N. Platte supply utilized in any month.

21. Add to Storage
This consists of the total water added to storage in Panhandle Reservoir #1 from the LaPrele supply and the North Platte supply. Separate accounts of each supply source are maintained in the reservoir operations.

22. Storage Releases
Storage releases were made from Panhandle Reservoir #1 to meet any plant demands not previously satisfied by the direct LaPrele supply to the plant and/or the direct N. Platte supply to the plant. It was assumed that a dead pool of 177 Ac-Ft would exist. If storage releases were required, releases were first made from the LaPrele account with the remainder being made from the North Platte account.

23. Evaporation
The evaporation for the month was calculated by averaging the beginning and end-of-month storage in order to determine the average monthly storage. From this, the average surface area was determined and the appropriate evaporation rate applied to that surface area (see Appendix A). The losses were distributed between the accounts by a ratio of that account's storage to the total storage.

24. Change in Storage
The monthly storage change was calcuated by subtracting storage releases and evaporation losses for each account from the respective add to storage account.

25. EOM Storage
The end-of-month storage was the sum of the previous month's EOM storage plus the present month's change in storage. Each of the accounts was handled in a similar manner. The water surface elevation and the water surface area were based on the total Panhandle Reservoir #1 EOM storage.

26. Groundwater Supplied to Plant
The groundwater supply was assumed to be a backup supply only. Groundwater was supplied to the plant only when the plant demand could not be met by one or a combination of direct LaPrele supply, direct N. Platte supply, and/or storage releases from Panhandle Reservoir #1. The groundwater was supplied from the Green Valley Well Field and the Morton's Well Field with each well field limited to a maximum of 2,000 Ac-Ft in any year. It was also assumed that the full 2,000 Ac-Ft from the Green Valley Well Field would be used before the Morton's Well Field would be utilized.

27. Plant Demand
The coal gasification plant demand schedule was provided by WyCoalGas, Inc.. (see Appendix A).

Table C-2 (concluded).

28. Total Plant Deliveries
The total plant deliveries consisted of the direct LaPrele supply, direct N. Platte supply, total Panhandle Reservoir #1 storage releases, and total groundwater supplied.

29. Plant Deficits
The plant deficit was the difference between the plant demand and the total plant deliveries.

30. LaPrele Association (Water Consumption)
This row represents the water used by the LaPrele Association in any month in comparison with flows that would have resulted had the LaPrele Unit not been there. This amounts to the water placed in the Association storage account plus the Association direct diversion less total return flows to the N. Platte System. Total return flows amount to 48% of total annual diversions of which 8% return to LaPrele Creek (refer to Row 2.1). Therefore, total return flows are six times row 2.1 for that month.

31. WyCoalGas (Water Consumption)
This row represents the total depletion by WyCoalGas on the North Platte System both from LaPrele Creek and directly from the N. Platte River. This amounts to the water placed in the WyCoalGas storage account in LaPrele less the total releases from the LaPrele WyCoalGas account plus the total water picked up at the WyCoalGas point of diversion on the N. Platte River.

TABLE C-3

THE WYCOALGAS WATER SUPPLY SYSTEM OPERATIONS MODEL--CALCULATION PROCEDURES

NOTES: 1. ALL VALUES TO BE IN KAC-FT; IF ABSOLUTE VALUE $\leq$ 0.005, SET #0.00 ANY "Σ" REFERS TO VALUES IN PRESENT WATER YEAR ONLY

2. CIRCLED NUMBERS CORRESPOND TO ITEMS LISTED IN TABLES 1 AND 2

1 = 1.054 x Input (Gage 06-6490)
2 = Input x (#Days in Month) ÷ 1,000
4 = Input
19 = Input
20 = 19 - 6.00; Min. of 0.00; Max. of {0.399 x (# Days in Month)}
28 = Input x (# Days in Month) ÷ 1,000
2.1 Oct. - May
Pr. Year Total (5 + 6) x Monthly Factor
June - Sept.
Σ(Pr. Mos. (5 + 6) x Monthly Factor
3 Lesser of: A) 2 - 2.1 ; Min. of Zero
B) 1 - 2.1 ; Min. of Zero
5 Lesser of: A) 4 B) 1 - 3 C) 0.3246 x (# Days in Month)
10 Lesser of: A) (19.54 - Pr. EOY 15) - Σ(Pr. Mos. 10)
B) 1 - 3 - 5
10B Oct. - Apr. Lesser of:
A) 10
B) $\underbrace{\{2.50 - \Sigma(\text{Pr. Mos. }10B)\}}_{\text{MIN. OF ZERO}} + \{\overbrace{10 - (2.50 - \Sigma(\text{Pr. Mos. }10B))}^{\text{MIN. OF ZERO}}\}\text{x }.25$ (MIN. OF ZERO)
C) 5.00 -Σ(Pr. Mos. 10B)
May - Sept. Lesser of:
A) 0.25 x 10
B) 5.00 -Σ(Pr. Mos. 10B)
10A = 10 - 10B
6 Lesser of: 1) Pr. Mo. 15A + 10A B) 4 - 5
7 = 4 - (5 + 6)
8 Base on Capacity of: {(Pr. Mo. 15)+(Pr. Mo. 15+10-6)}÷2}x(# Days in Month)÷1,000
20A Lesser of: A) 20 B) 28-(0.90x8); Min. of 0.00
20B Lesser of: A) 20-20A
B) (0.399 x # Days in Month) - (0.90 x 8) - 20A
C) 26.54- Pr. EOY 26B-Σ(Pr. Mos. 20B)
D) 26.54 - {Pr. Mo. 26 + ((8x0.90) - 28; Min of 0.00)} ; Min. of 0.00
20C = 20 -(20A + 20B)
20D = 20A + 20B
9 Oct. - Aug.
Check: is 20 > 0
Yes - Lesser of: A) {28 - (0.90x8)-20A}÷0.90; Min. of 0.00
B) Pr. Mo. 15B + 10B - 8 - 0.015
No - Lesser of: A) {28 - (0.90 x 8)}÷0.90; Min of 0.00
Oct.-Apr.B) 2.00 - {Σ(Pr. Mos. 6) + 8}; Min. of 0.00
May- Aug.B) 4.50 - {Σ(Pr. Mos. 6) + 8}; Min. of 0.00
C) Pr. Mo. 15B + 10B - 8 - 0.015; Min. of 0.00
Sept. = Pr. Mo. 15B + 10B - 8 - 0.015; Min. of 0.00

ABBREVIATIONS: Pr.=Previous Mo.=Month's Mos.=Months'
EOY=End-of-Year Max.=Maximum Min.=Minimum

Table C-3 (continued).

11 = 8 + 9 + 6
12 = 1 - (3 + 5 + 10)
13 Lesser of: A) Pr. Mo. 15 + 10 - 11
B) (Evap. Rate) X (Surface Area @ Capacity of $\frac{\text{Pr. Mo. 15} + (\text{Pr. Mo. 15} + 10 - 11)}{2}$)
13A Check: is (Pr. Mo. 15 + 10 + 11) >0.001
Yes: 13A = 13 x $\frac{\text{Pr. Mo. 15A} + \text{10A} - 6}{\text{Pr. Mo. 15} + 10 - 11}$ No: 13A = 0
13B = 13 - 13A
14 = 10 - 11 - 13
14B = 10B - (8 + 9) - 13B; Min of -(Pr. Mo. 15B)
14A = 14 - 14B
NEW 6 = 10A - 13A - 14A
15 = Pr. Mo. 15 + 14; Min of 0.00
15B = Pr. Mo. 15B + 14B
15A = 15 - 15B
15C Elevation (In Feet) at Storage Capacity of 15
15D Surface Area (In Acres) at Storage Capacity of 15
15.1 Oct. - Apr.
= 2.1 + 8 + 9 + 12
May - Sept.
= .48 (2.1 + 3) + 8 + 9 + 12
16 = 8 + 9
17 = 16 x 0.10
18 = 16 x 0.90
18A Lesser of: A) 18 B) 28
18B = 18 - 18A
18C = (Pr. Mo. 26 + 18B) -26.54; Min. 0.00
21A = 18B - 18C
21B = 20B
21 = 21A + 21B
22 Lesser of: A) 28 - 18A - 20A
B) Pr. Mo. 26 - 0.18; Min. of Zero
22A Lesser of: A) 22 B) Pr. Mo. 26A
22B = 22 - 22A
23 Lesser of: A) (Pr. Mo. 26 + 21 - 22)
B) (Evap. Rate) x (Surface Area @ Capacity of $\frac{\text{Pr. Mo. 26} + (\text{Pr. Mo. 26} + 21 - 22)}{2}$)
23A Check: Is (Pr. Mo. 26 + 21 - 22) >0.001
Yes: 23A = 23 x $\frac{\text{Pr. Mo. 26A} + \text{21A} - \text{22A}}{\text{Pr. Mo. 26} + 21 - 22}$ No: 23A = 0

23B = 23 - 23A
25 = 21 - 22 - 23 - 24
25A = 21A - 22A - 23A - 24A
25B = 21B - 22B - 23B - 24B
26 = Pr. Mo. 26 + 25; Min. of 0.00
26A = Pr. Mo. 26A + 25A; Min of 0.00
26B = Pr. Mo. 26B + 25B; Min of 0.00
26C Elevation (in feet) at Storage Capacity of 26
26D Surface Area (Acres) at Storage Capacity of 26
27 Lesser of: A) (28-20A-18A-22)
B) 4.00-Σ(Pr. Mos. 27)
27A Lesser of: A) 27
B) 2.00-Σ(Pr. Mos. 27A)
27B = 27 - 27A
29 = 20A + 18A + 22 + 27

Table C-3 (concluded).

30 = 28 - 29

31 = 10A - (6.0x 2.1) + 5

32 = 10B - 16 + (18 - 18C) + 20D

TABLE C-4 THE WYCOALGAS WATER SUPPLY SYSTEM OPERATIONS MODEL--BASIC DATA

OPERATION STUDIES DATA

(2) SENIOR RIGHTS DEMAND
(1969 BUREC REPORT)

$1276 \text{ ACRES} \times \frac{1 \text{ CFS}}{70 \text{ ACRES}} \times \frac{1.98347 \text{ AC-FT/DAY}}{1 \text{ CFS}} = 36.16 \frac{\text{ACRE-FEET}}{\text{DAY}}$

MAY	JUNE	JULY	AUGUST	SEPTEMBER
1.121 KAC-FT	1.085	1.121	1.121	1.085

(4) TOTAL ASSOCIATION DEMAND (INCLUDES CARRIER RIGHTS) 11,454 ACRES
(1969 BUREC REPORT—AVG. VALUES)

1,149.5 ACRES CARRIER RIGHTS
10,304.5 ACRES ASSOCIATION
} 5% OF DEMAND MET BY "INTERNAL" RETURN FLOWS

MAY	JUNE	JULY	AUGUST	SEPTEMBER
2.829 KAC-FT	5.549	9.793	8.814	7.182

(8) LAPRELE SEEPAGE (1980; TIPTON & KALMBACH, INC.)
(LINEAR REGRESSION FROM COLLECTED DATA)

CAPACITY (AC-FT)	SEEPAGE (AC-FT/DAY)
0	0
250	0
416	1.67
961	3.47
1,600	4.76
4,000	7.48
8,000	11.62
12,000	15.79
16,000	19.93
20,000	24.08

BANNER ASSOCIATES, INC.
620 Plaza Court
LARAMIE, WYOMING 82070
(307) 745-7366

JOB WY COAL GAS 1803-3
SHEET NO. 2 OF 4
CALCULATED BY SRZ DATE
CHECKED BY DATE
SCALE

Table C-4 (continued).

(2.1) LAPRELE CREEK RETURN FLOWS 8% OF IRRIGATION FLOWS (1969 BUREC REPORT)

	LAPRELE CREEK × MONTHLY DISTRIBUTION	
OCT	(.08 X .08)	.0064
NOV	(.08 X .06)	.0048
DEC	(" X .05)	.0040
JAN	(" X .04)	.0032
FEB	(" X .04)	.0032
MAR	(" X .03)	.0024
APR	(" X .04)	.0032
MAY	(" X .07)	.0056

FOR JUN-SEP, IRR. PROJECTIONS FOR YEAR TOTAL BASED ON (AVG. Σ IRR.) % of (AVG. YEAR TOTAL) ; (LP.002 2/23/81)

	MONTHLY DISTRIB. × LAPRELE CREEK × PROJECTION FACTOR	
JUNE	(.10 X .08 X 5.625)	.0450
JULY	(.16 X .08 X 2.016)	.0258
AUG	(.18 X .08 X 1.125)	.0162
SEP	(.15 X .08 X 1.008)	.0121

LAPRELE CREEK RETURN FLOWS
8% OF THE TOTAL RETURN FLOWS OF 48%
∴ TOTAL RETURN FLOWS = 6.0 X LAPRELE RETURNS

BANNER ASSOCIATES, INC.
P. O. Box 550 620 Plaza Court
LARAMIE, WYOMING 82070
(307) 745-7366

Table C-4 (continued).

(13) & (23) EVAPORATION RATES

OCT	0.17 FT/ACRE	APR.	0.24 FT/ACRE
NOV	0.10	MAY	0.32
DEC	0.09	JUN	0.36
JAN	0.09	JUL	0.44
FEB	0.08	AUG	0.40
MAR	0.14	SEP	0.26

(15) LAPRELE RESERVOIR (1980 REPORT; TIPTON & KALMBACH, INC.)

ELEV.	AREA (ACRES)	CAPACITY (AC-FT)	
5372	0	0	
5383	2.73	15	DEADPOOL
5400	11.98	140	
5410	17.82	289	
5420	42.18	589	
5430	71.62	1,158	
5440	126.98	2,151	
5450	209.02	3,831	
5460	285.98	6,306	
5470	383.82	9,655	
5480	483.38	13,991	
5490	626.82	19,542	

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JOB: WY COAL GAS 1803-3
SHEET NO. 4 OF 4
CALCULATED BY: SRZ DATE
CHECKED BY DATE
SCALE

Table C-4 (concluded).

(26) PANHANDLE RESERVOIR #1

ELEV.	AREA (ACRES)	CAPACITY (AC-FT)	
4860	0	0	
4870	4.0	14	
4880	34.5	177	ASSUMED DEADPOOL
4890	65.4	656	
4900	119.4	1563	
4910	181.5	3059	
4920	261.8	5268	
4930	369.3	8,375	
4940	509.8	12,780	
4950	684.6	18,735	
4960	878.4	26,539	

(28) WY COAL GAS PLANT DEMAND

OCT. & SEPT.	13.65 AC-FT/DAY
NOV. – AUG.	17.06 AC-FT/DAY

PRODUCT 204-1 NEBS Inc., Groton, Mass. 01450